IRRI HIGHLIGHTS 1988

"...ability to bring together the basic research coming from academic and other institutions in the more advanced countries with the practical experience of fieldwork in developing countries imparts a synergism that enhances the effectiveness of the center's research programs... National and international efforts are mutually reinforcing; each benefits from the strengths of the other..."

International Rice Research Institute

Her Excellency Corazon C. Aquino, President of the Republic of the Philippines, delivered the 1986 World Food Day address at IRRI 15 October.

IRRI IN THE PHILIPPINES

Her Excellency Corazon C. Aquino, President of the Republic of the Philippines, visited IRRI on 15 October 1986. During that visit she delivered the 1986 World Food Day address, dedicated IRRI's new Biotechnology and Seed Health Laboratory, and reviewed IRRI research programs.

In her address, she spoke to some of the issues relating to agricultural research in general, to host country collaboration and cooperation, and to the challenges facing nations and the international agricultural research system. Some excerpts follow:

"Today, some 300 million tons of food grains are stored in the warehouses of both developed and developing countries. Most developing countries have been able to raise domestic food production above the levels of their population growth.

"How did this happen?

"Scientific research conducted by IRRI and other similar programs and research centers has been the principal catalyst of change . . .

"The green revolution in rice and other crops has brought us time. Time in which to get our global house in order, to find the means and the political will to distribute the growing wealth of our world more equitably to those who still do not have the basic necessities of life, before their numbers outstrip the ability to feed them . . .

"I should like to thank the donors of IRRI for their support and concern for the welfare of our people, and the peoples of other developing countries of the world. I should also like to appeal for their continued and increased support. We are proud that the Philippines is the home of IRRI and grateful that the honor for its achievements has in some small measure reflected on us who have hosted its efforts, even as we have enjoyed its benefits."

IRRI Highlights 1986

INTERNATIONAL COLLABORATION
The Power of Partnership in Science

1987
International Rice Research Institute
Los Baños, Laguna, Philippines
P.O.Box 933, Manila, Philippines

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockfeller Foundations with the help and approval of the Government of the Philippines. Today IRRI is one of the 13 nonprofit international research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of 50 donor countries, international and regional organizations, and private foundations.

IRRI receives support, through the CGIAR, from a number of donors including the Asian Development Bank, the European Economic Community, the Ford Foundation, the International Development Research Centre, the International Fund for Agricultural Development, the OPEC Special Fund, the Rockefeller Foundation, the United Nations Development Programme, the World Bank, and the international aid agencies of the following governments: Australia, Belgium, Canada, China, Denmark, France, Federal Republic of Germany, India, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Philippines, Saudi Arabia, Spain, Sweden, Switzerland, United Kingdom, and United States.

The responsibility for this publication rests with the International Rice Research Institute.

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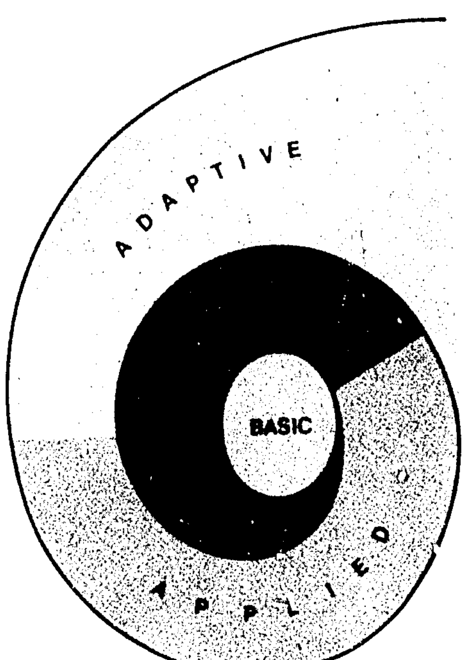
INTERNATIONAL COOPERATION
The Power of Partnership in Science

Cover quotation: p. 189 in PARTNERS AGAINST HUNGER, Warren Baum, 1986.

INTRODUCTION

wo billion people in China, India, Indonesia, and Bangladesh, along with millions more in other countries, depend on rice for more than half the protein and calories they consume. The number grows daily. Food security for much of the developing world hinges on the capacity of farmers to increase rice production from existing ricelands at some 3% annually over the next several decades.

Meeting the demand for increased productivity depends upon a stream of new knowledge about rice and its environments and new technology to utilize that knowledge. IRRI is the nexus of a dynamic, interactive system striving to meet that research goal. Our collaborations with basic and strategic research institutions dovetail with the strategic research we undertake at IRRI. The applied research we undertake dovetails with our collaborations with national agricultural research programs and their own applied and adaptive research activities (Fig. 1).

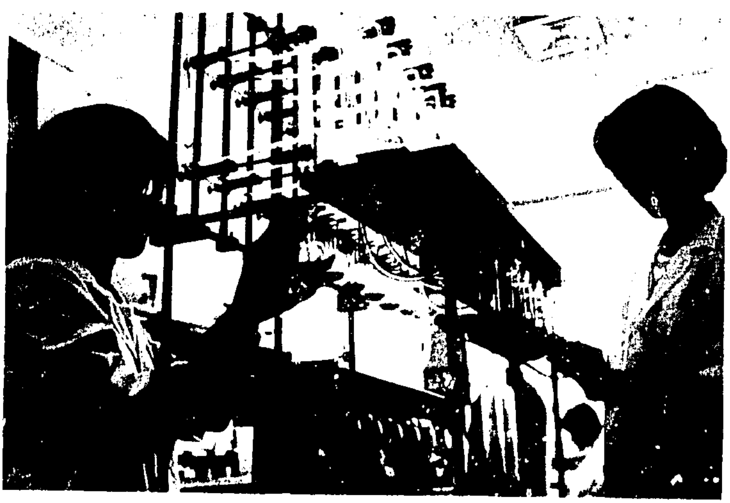


1. Basic research builds knowledge. Strategic research selects from that knowledge the tools with which to solve specific research problems. But those solutions are still far from applicable technology. Applied research builds from basic and strategic research to develop new technology. Adaptive research modifies that technology to fit specific situations.

We place major emphasis on fostering the expansion of a global family of research institutes and scientists dedicated to improving the productivity, profitability, stability, and sustainability of rice and rice farming systems. We rely on numerous pathways of collaboration — interactions with advanced research institutions all over the world; cooperation among scientists of many research disciplines and laboratories; our own global research services; the global research networks, and our agreements with national agriculture research system programs. In all these collaborations, research and training go hand in hand.

Nearly 5,000 rice scientists from 78 countries have been trained through IRRI so far. Many of those working for master's and doctoral degrees have been trained jointly with the University of the Philippines at Los Baños, on whose campus IRRI is located. Countless other scientists have benefited from the growth that comes through professional collaboration. Several countries that once had only a few personnel trained to undertake problem-solving rice research now have research institutions staffed and equipped at a professional level. Many IRRI alumni occupy responsible administrative positions in their national rice research institutes and research systems.

Progress in improving rice production and productivity in irrigated and favorable rainfed areas can be attributed, to a considerable extent, to these meaningful partnerships. We expect research on the less favorable rice



environments of the world to be as productive. And we expect progress on both frontiers to accelerate because of the strength of our historical collaborations and the dynamism of our new collaborations.

STRATEGIC RESEARCH COLLABORATION

evelopments on many frontiers of science and technology are explosive. Biotechnology and genetic engineering...micro-electronics and computer sciences...satellite imagery and educational technology. As we look ahead, it is obvious that our patterns of collaboration and cooperation will continue to evolve as we exploit the emerging opportunities.

Already, the collaborations we have in highly technical and innovative research areas are stimulating all our research and training. The researcher interactions complement the resources and capabilities of the IRRI staff and the resources and capabilities of various national programs, particularly in the use of innovative research techniques.

Our collaborations with advanced research institutions involve numerous complex interactions. Some include the assignment of scientists to IRRI to conduct research of interest to IRRI and to the organizations seconding the scientists. In other partnerships, advanced scientific institutions apply sophisticated analytical techniques in their own laboratories to help resolve problems identified at IRRI. In 1986, we collaborated in more than 70 projects with advanced research centers in different parts of the world.

Many of the research areas related to rice are also concerns of other international institutions: insect pest physiology and ecology (International Centre of Insect Physiology and Ecology), fertilizer technology development (International Fertilizer Development Center), soil (International Board for Soil Research and Management) and water management (International Irrigation Management Institute), agricultural policy analysis (International

COLLABORATION WITH ADVANCED RESEARCH INSTITUTES

In establishing collaborative basic and strategic research relationships, IRRI applies these basic principles:

- *The research is identified by IRRI as necessary to solving specific problems.*
- *The collaborating institution has a clear comparative advantage and competence in the type of work involved.*
- *The reasonable expectation is that the research will yield significant results within a given time.*
- *Necessary funding is available.*

Such collaboration helps us capture the power of upstream research for solving complex downstream problems. In addition, it helps to advance the frontiers of knowledge, a basic requisite for a continuous flow of new technologies.

Food Policy Research Institute (IFPRI). Sister institutions funded by the Consultative Group on International Agricultural Research (CGIAR) that include rice research in their agendas are the International Institute of Tropical Agriculture (IITA) in Nigeria, the West Africa Rice Development Association (WARDA), and the International Center for Tropical Agriculture (CIAT) in Colombia.

The International Service for National Agricultural Research (ISNAR) is concerned with strengthening national research systems and contributes to the increased effectiveness of rice research and development more generally. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Maize and Wheat Improvement Center (CIMMYT) have mandates for crops that are of interest in rice-based farming systems.

In addition, nationally-funded organizations, such as the Centre International de Recherche Agronomique pour le Developpement (CIRAD) in France, pursue activities closely related to global interests in rice research and development.

Through collaboration with these — and many other institutions — IRRI seeks to identify and capitalize on all the complementarities that exist. A few reports of the progress on many research fronts follow.

Genetic engineering

The understanding of rice genetics lags far behind that of other important food crops. To accelerate our application of emerging techniques in genetic engineering to improve rice, we have intensified our research on basic genetics and our collaborations with basic research institutes.

Genetic markers and trisomic stocks have been assembled or produced; linkage maps have been associated with respective chromosomes through the primary trisomic technique, and additional marker genes are being mapped. Such research on linkage mapping is expanding through the Rockefeller Foundation-supported wide hybridization project.

Of the 22 known loci of isozymes of rice plumules, only 3 had been mapped. Now 12 more have been assigned to their respective linkage groups using the trisomic technique. This brings the total of localized isozymes which exhibit variation among cultivated rices to 15. In cooperation with Cornell University, USA, the restriction fragment length polymorphism (RFLP) genetic map of rice is being prepared — with the goal of more than 100 DNA markers mapped by 1990.

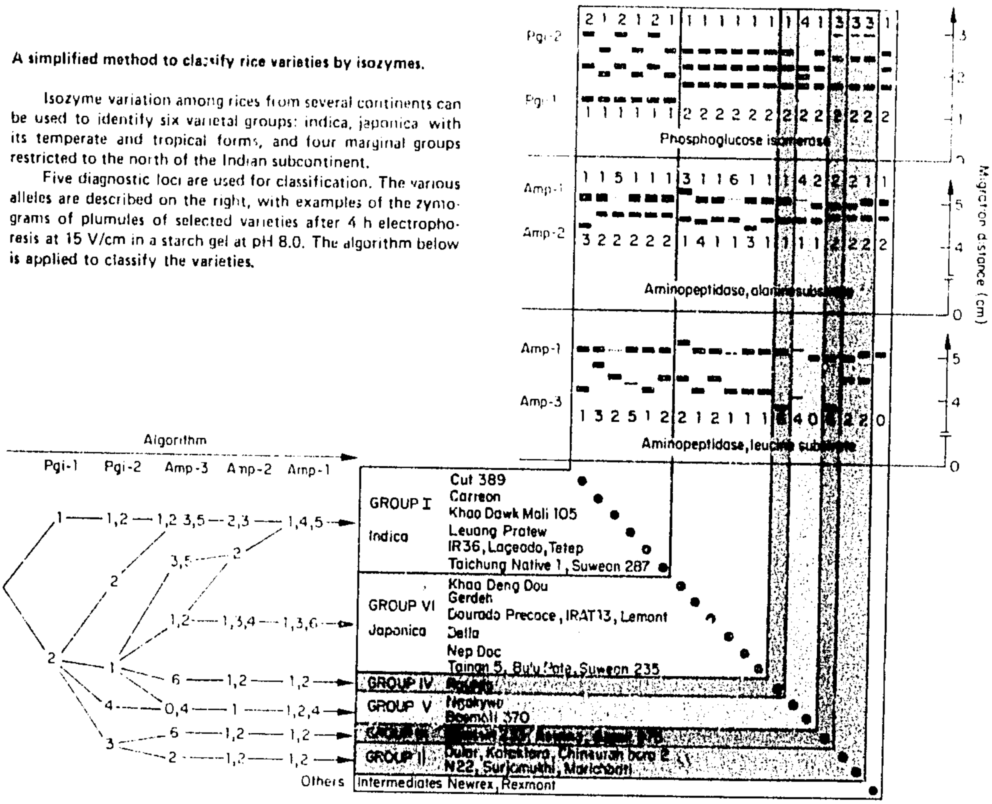
The 15 localized isozymes which exhibit variation among cultivated rices provide convenient marker genes to use in conventional as well as innovative and biotechnology-based breeding. Another useful application is subspecific classification of varieties for better exploitation of genetic resources. We have analyzed materials from Brazil, Korea, India, Vietnam, USA, and the Institute for Research in Tropical Agriculture (IRAT) and have developed a simplified classification method that is reliable, fast, and cheap (Fig. 2).

2. Simplified method for subspecific classification by isozymes of rice varieties to better exploit genetic resources. This method is reliable and fast, and demands only a modest research investment.

A simplified method to classify rice varieties by isozymes.

Isozyme variation among rices from several continents can be used to identify six varietal groups: indica, japonica with its temperate and tropical forms, and four marginal groups restricted to the north of the Indian subcontinent.

Five diagnostic loci are used for classification. The various alleles are described on the right, with examples of the zymograms of plumules of selected varieties after 4 h electrophoresis at 15 V/cm in a starch gel at pH 8.0. The algorithm below is applied to classify the varieties.



We have already begun wide hybridization. Wild species of rice possess genes of potential value for improving cultivated varieties, but until recently these genes could not be reached by rice breeders because of crossing and recombination barriers. Through embryo rescue techniques, we have been able to produce hybrids between *O. sativa* and *O. officinalis*, a wild species with high resistance to brown planthopper and whitebacked planthopper. We selected lines from a second backcross which look like *O. sativa* but which are resistant to brown planthopper and whitebacked planthopper. The next step is to combine these new sources of resistance with other breeding lines (Fig. 3).

Useful traits are present in other wild species; we are expanding our research in utilizing these traits for rice improvement.

Protoplast culture and fusion between wild rices and cultivated species could solve prefertilization incompatibilities. Regeneration of plants through *in vitro* culture is a prerequisite to successful protoplast fusion. In addition to *O. perennis*, which has shown regeneration in somatic cultures, we have produced callus from *O. nivara* and *O. rufifogon/O. sativa* and are studying regeneration from the induced calli. In addition, we have successfully germinated immature seeds of *Schlerophyllum coarctatum*, a wild species which is an important source of genes for salinity and submergence tolerance. Plants have been raised from protoplasts of a japonica variety at the University of Nottingham, U.K.

3. Through embryo rescue, we have been able to produce hybrids between cultivated rice and *O. officinalis*, a wild species with resistance to brown planthopper and whitebacked planthoper. Backcrosses of the F_1 hybrids to *O. sativa* resulted in progenies with inherited resistance.

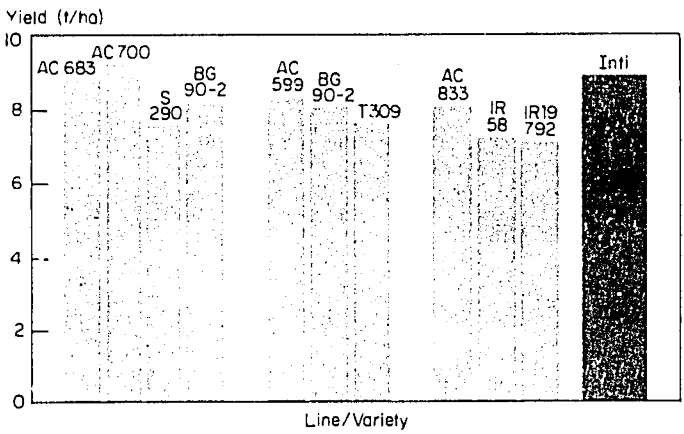
We are using anther culture to develop breeding lines suited to Latin American conditions in our collaborative project with the Universidad Nacional Pedro Ruiz Gallo, Peru. From 8 indica crosses from Peru, 224 lines have been selected and sent to Peru for testing under local conditions.

Four anther culture lines from F_1 IRRI crosses were sent to Peru for evaluation of agronomic characteristics. All lines yielded higher than both parents, and one outyielded the local check (Fig. 4).

Work with the Rural Development Administration (RDA) of Korea in developing cold tolerant lines continues. The 64 lines sent to Korea this year brought the number being evaluated to 1,248 in 3 yr. IRRI and RDA/Korea are using the same media and *in vitro* culture.

Cooperative experiments with the Tissue Culture for Crops Project, Colorado State University, USA, are exploring the use of biotechnology in improving rices for adverse environments. Some somaclonal variants isolated already have produced superior breeding materials for salt tolerance.

We studied physiological and genetic aspects of tolerance for problem soils in cooperation with the University of Sussex, England. The research has been directed mainly toward explaining the basic mechanisms of salt tolerance in rice. The importance of growth rate, tissue tolerance, leaf compartmentation, and root selectivity of sodium uptake for salinity tolerance in rice has been established and screening methods have been developed (Fig. 5).



4. Of the 4 anther culture lines sent to Peru for agronomic evaluation, 1 line — AC700 — even outyielded the local check.

5. Increased salt tolerance of 2 anther-cultured lines — TCP6533 and TCP6533-3 — from the cross IR46/Pokkali.

Tungro virus

We have identified rice variety Balimau Putih as tolerant of a tungro composite caused by tungro bacilliform and tungro spherical viruses. Balimau Putih infected by both viruses does not show typical symptoms — healthy and infected plants do not differ in height and vigor. Serological tests showed that the viruses did not multiply in infected Balimau Putih plants as they did in susceptible TN1. Yield reduction was about 20% in infected Balimau Putih, 90% in infected TN1.

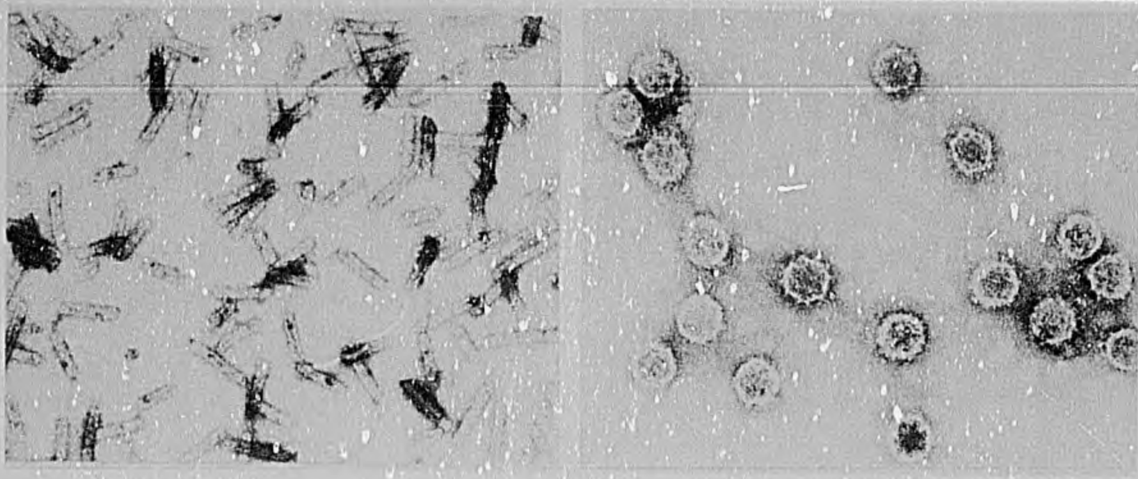
Serodiagnosis of rice viruses

Serology is essential in virus research. We have isolated pure forms of rice tungro bacilliform and spherical viruses from rice plants infected with tungro and have purified rice grassy stunt and ragged stunt viruses (Fig. 6).

For immunization, we separately injected purified viruses into rabbits and obtained antiserum specific to each virus. The serological tests we have developed (enzyme-linked immunosorbent assay and latex) are efficient in detecting the viruses in rice plants and vector insects. The latex test is particularly simple and does not require sophisticated laboratory equipment to run.

We also obtained monoclonal antibody to rice grassy stunt virus in collaboration with the American Type Culture Collection, Maryland, USA.

Using the antisera, we can make major progress on understanding virus resistance and epidemiology. Because



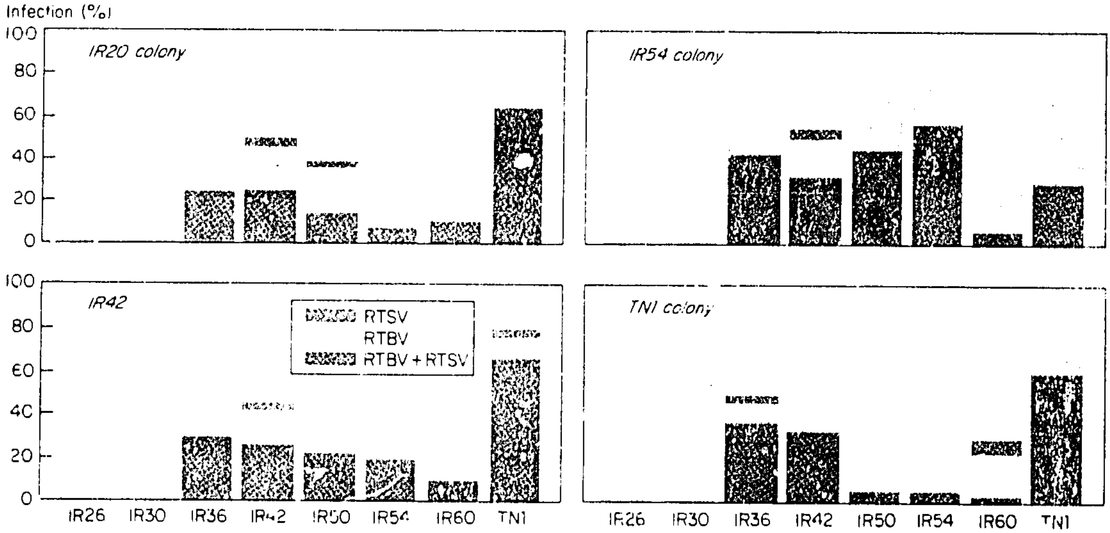
6. Electron micrographs of purified rice tungro bacilliform virus (left) and rice ragged stunt virus (right). ×50,000.

the antisera available have been very limited, serology had not been widely adopted in most countries of South and Southeast Asia. Now, antisera from IRRI have been applied in national research programs on virus resistance, diagnosis, and epidemiology at 12 institutes in 7 countries. A special training course for serological techniques and their application in the study of virus resistance and virus ecology has been started.

Collaborative research on rice tungro virus disease at the Maros Research Institute for Food Crops, Indonesia, is aimed at determining the effects of selected green leafhopper colonies on tungro transmission. Because tungro is a composite disease caused by two rice tungro viruses — bacilliform and spherical — inoculated plants were indexed serologically.

Four green leafhopper colonies, which have been maintained on IR20, IR42, IR54, and TN1 at MORIF since 1982, were used for transmission. IR20 has resistance derived from TKM6, IR42 from Ptb 18, and IR54 from Gam Pai 30-12-15. IR26 and IR30 were used as the differential varieties for the IR20 colony. Seedlings were inoculated in test tubes at one insect per seedling.

Only the IR54 colony gave distinct differential reactions, with higher infection rates on IR50 and IR54 (Fig. 7). That colony transmitted both the rice tungro bacilliform virus (RTBV) and rice tungro spherical virus; other colonies transmitted RTBV alone. In a preference test, the IR54 colony alighted more on IR50 and IR54



7. Reactions of IR varieties artificially inoculated with tungro composite disease caused by RTBV and RTSV, using selected green leafhopper colonies

seedlings, resulting in more disease transmission. The IR54 colony also caused significantly higher infection rates on other varieties with the Gam Pai genes.

In natural field infestations in South Sulawesi Indonesia, some IR varieties had relatively high infection, indicating the presence of green leafhoppers that can overcome varietal resistance.

Resistance to brown planthopper

We are collaborating with the Tropical Development and Research Institute (TDRI), London, to determine the mechanisms of rice resistance to brown planthopper. The acceptability of a variety by brown planthoppers can be quantified by the time from when the insect starts probing to the time of sustained feeding. Using a high-resolution video system, we detected a resistance mechanism associated with the plant surface. Data suggest antibiosis, a non-preference mechanism, that is stronger in resistant variety IR62 than in IR46.

When we electronically monitored brown planthopper feeding on other varieties, we found no difference in the insect's ability to locate its primary feeding site (the phloem) regardless of the resistance of the variety.

Tolerance for P deficiency

Varietal tolerance for P deficiency is important, not only in Oxisols, Andosols, and acid sulfate soils, but also in areas with multiple stresses. Varieties that can exploit soil and fertilizer P efficiently continue to be identified. Confirmed efficient P users are medium- to long-duration varieties. The use of P-efficient varieties in conjunction with P fertilization and organic amendments gave a response of 1.7 t/ha and increased available P in the soil.

Of three rice races tested in an acid upland soil, the japonica entries were found to be less susceptible to aluminum and manganese toxicities and to have better vigor than the aus and indica entries.

In an acid aerobic soil where mineral analyses revealed deficiencies of N, P, Ca, and Si plus low Fe-to-Mn ratio, UPL Ri-7 developed by the rice breeders of the University of the Philippines at Los Baños (UPLB) gave the highest yield.

Studies on the growth limiting factors of problem soils continue and methods for mass screening and for determining the mechanisms of tolerance for toxicities and nutrient deficiencies are being developed. Using chlorophyll fluorescence for mass screening against such soil stresses as salinity and acid sulfate conditions shows promise as a tool for rapid selection of resistant rices.

Biological control of fungal diseases

Antagonistic bacteria from ricefields potentially could control rice diseases where host plant resistance is not effective or where breeding efforts have not focused on resistance. In collaboration with Korea, we isolated 167 bacteria from Korean ricefields; 58% inhibited most rice fungal pathogens, including *Pyricularia oryzae*. Most of the bacteria which produced blue fluorescent pigment on King's Medium B were antagonistic to at least three rice fungal pathogens.

Primary screening for the effectiveness of promising isolates will be tested in Korean experiment stations in 1987. Similar projects are planned with scientists in China, India, and Thailand.

We collaborated with the Department of Microbiology and Microbial Genetics at the University of Ghent, Belgium, to isolate and test the taxonomy of 23 of the bacteria strains. On the basis of phenotypic and biochemical test, the bacteria were identified as *Bacillus pumilus, B. laterosporus, Pseudomonas aeroginosa, P. fluorescens,* and *P. rebrisubalbicans. Serratia marcescens* and a species of *Erwinia* also were identified.

As part of the application of biotechnology to rice improvement, scientists from diverse disciplines discussed the problems and research strategies related to blast, bacterial blight, and virus diseases at a Rockefeller Foundation-sponsored workshop this year.

Because pathogenic variation has been a problem in developing durable resistance, research collaborations with the University of Wisconsin and Kansas State University, USA, will study the genetics of host-pathogen interactions. The initial focus will be on genetic virulence in *Pyricularia oryzae* and *Xanthomonas campestris* pv. *oryzae*. The collaborations also will provide training opportunities for scientists in national agricultural research systems.

Genetic polymorphism in green leafhopper

Genetic polymorphism in *Nephotettix virescens* was studied using horizontal starch gel electrophoresis. Of the 18 enzyme loci studied, 14 were polymorphic. Other enzyme

8. One of the more than 300 local isolates of *Bacillus thuringiensis* in the germplasm collection at the Institute of Biotechnology and Applied Microbiology, University of the Philippines at Los Baños, being prepared at IRRI for screening against 1 of 6 lepidopterous pests of rice.

loci are now being investigated to determine the genetic variability of *N. virescens.*

Bacillus thuringiensis — an indigenous microbial pesticide

Insect pathogens that control lepidopterous pests can be cultured in large quantities to be sprayed like an insecticide. The Institute of Biotechnology and Applied Microbiology, UPLB, has collected more than 300 local isolates of *Bacillus thuringiensis* (Bt) (Fig. 8). Laboratory tests found more than 50% toxicity in a number of them: against green hairy caterpillar *Rivula atimeta,* 150; green semilooper *Naranga aenescens,* 98; caseworm *Nymphula depunctalis,* 72; leaffolder *Cnaphalocrocis medinalis,* 71; yellow stem borer *Scirpophaga incertulas,* 7, and striped stem borer *Chilo suppressalis,* 6.

A proteinaceous toxic crystal formed in Bt spores is the material sprayed on the rice crop. Insect larvae stop feeding 6-12 hours after eating the Bt crystals and die of starvation within 2 days.

After the toxicity of pathogen isolates against armyworms and other lepidopterous pests is evaluated, several pathogens will be selected for large-scale production and field testing.

Bt is nontoxic to humans, natural enemies of rice pests, and the environment.

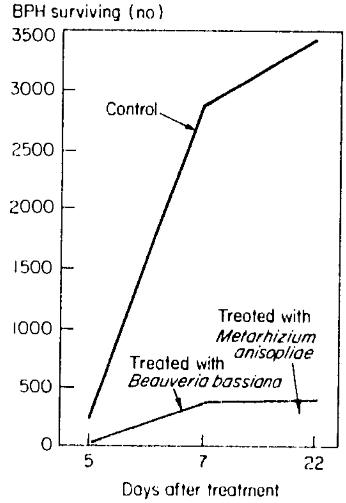
Biological control of brown planthopper

We field-tested several fungal pathogens against the brown planthopper in cooperation with the Institute of Agricultural Sciences, Office for Rural Development, Korea. A small mass production unit in the laboratory produced the infective fungal material that was applied by conventional methods.

The fungi significantly prevented brown planthopper population buildup (Fig. 9, 10, 11).

Botanicals for insect control

We expanded our studies on neem *Azadirachta indica* seed derivatives for pest management. National programs in Bangladesh, China, India, and the Philippines are collaborating with IRRI and the East-West Center, Hawaii, USA, in adaptive experiments in farmers' fields.



9. Survival of brown planthoppers (BPH) treated with *Metarhizium anisopliae* and *Beauveria bassiana* fungi.

10. A brown planthopper infected with *Metarizhium anisopliae* fungus.

11. A brown planthopper infected with *Beauveria bassiana* fungus.

12. Neem seed bitters (limonoids) are a crystalline brownish powder that is water soluble and can be used in a spray to control black bug.

A simple procedure was developed to extract neem seed bitters (limonoids) as a crystalline brownish powder (Fig. 12). The powder is water soluble, relatively photostable, and nonphytotoxic. A 500-ppm solution sprayed on rice plants checked brown planthopper, whitebacked planthopper, and green leafhopper populations. With both 100 and 500 ppm sprays, the first generation brown planthopper males to emerge had significantly low frequencies of meiotic cells, reducing their insemination potential.

Natural enemies of rice-damaging insects were not harmed by the neem spray. The mirid predator continued to consume about 50% of the eggs and about 25% of the brown planthopper nymphs (Fig. 13). The extract, which also has systemic action, is being evaluated in field trials.

Soluble Zn^{2+} in Zn-deficient soils

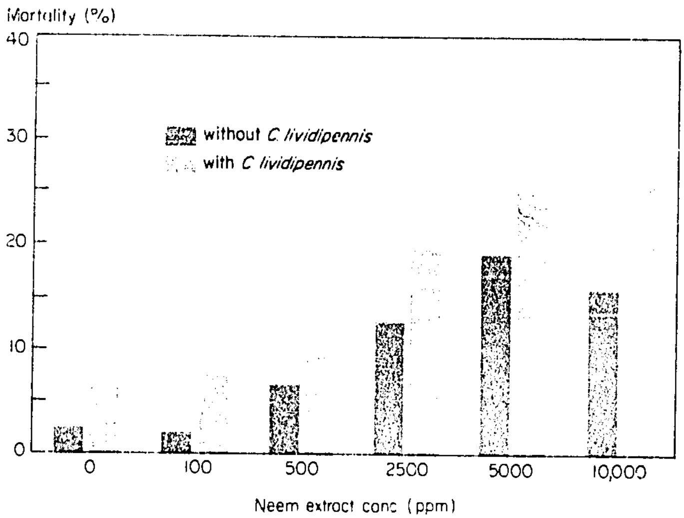
A scientist from the University of Minnesota, St. Paul, USA, is investigating at IRRI the factors controlling soluble Zn^{2+} in flooded soils. After N deficiency, Zn deficiency may be the most widespread nutrient deficiency in flooded rice.

Results so far suggest that the formation of ZnS, possibly in a mixed phase with Fe^{2+}, is an important factor in the control of soluble Zn^{2+}. But soil solutions remain highly oversaturated (3-4 orders of magnitude) in respect to the precipitation of crystallized ZnS (wurtzite). This suggests severe kinetic constraints on the formation of separate phase ZnS.

Sulfide ion concentrations appear to be controlled by the formation of amorphous FeS, but the $S^{=}$ concentrations are 3 to 10 times greater than that predicted by the solubility of pure amorphous FeS. Iron and Mn^{2+} are also oversaturated in respect to the formation of separate phase phosphates and carbonates.

Simplified technique to estimate ammonia volatilization

In our collaboration with the Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Plant Industry, Australia, we used a simplified horizontal transport method to estimate ammonia loss under different fertilizer management treatments. A ^{15}N balance technique



13. Mortality of brown planthopper nymphs on rice plants sprayed with neem seed extract, with and without the mirid predator *Cyrtorhinus lividipennis*

was used to estimate total N loss from irrigated ricefields at 3 Philippine sites over 2 years.

The simplified technique indicated that ammonia volatilization loss from the 3 sites was 30 54% when N fertilizer was surface-applied into floodwater at 10 days after transplanting (the common practice used by many Asian farmers) (Fig. 14).

Basal incorporation of N fertilizer without standing water but with soil saturation maintained for 4 days greatly minimized ammonia loss and increased crop recovery of applied N and yield.

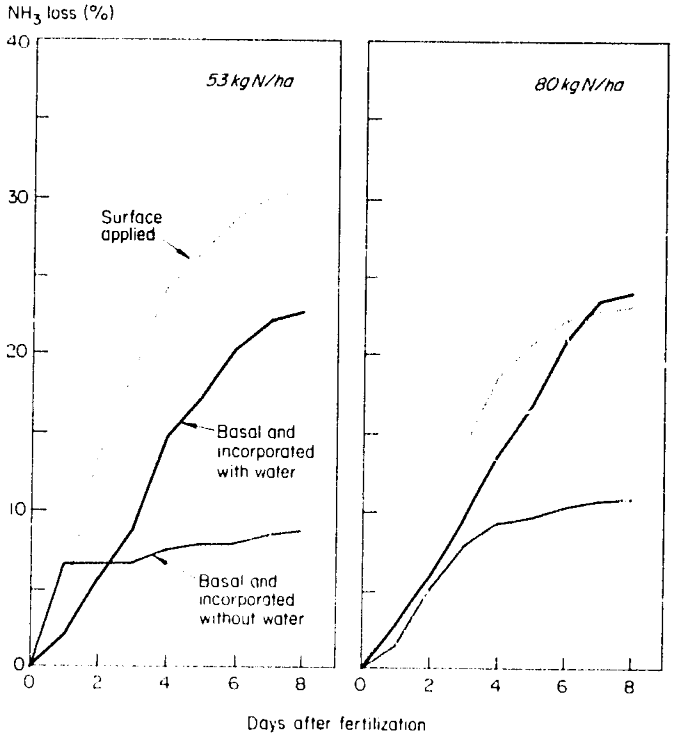
The estimated nitrification-denitrification loss was generally unaffected by fertilizer application rate and method.

Aggregation in puddled soils

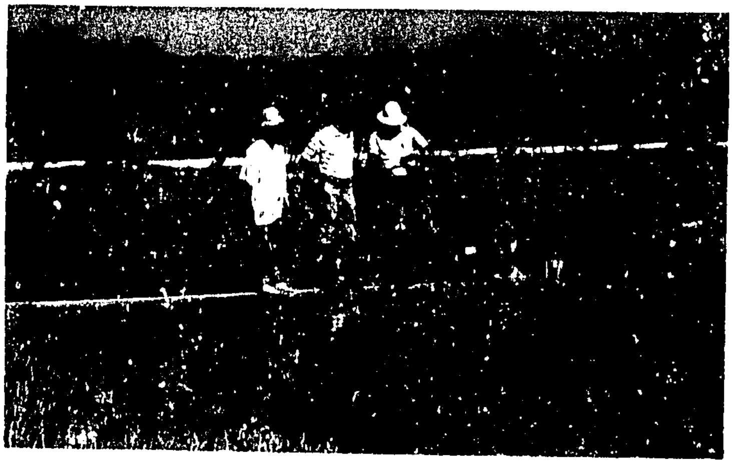
The cloddy, poorly aggregated soil left after rice hinders the establishment of second crops. We studied the formation of soil aggregates and their stability in puddled soils after rice in collaboration with the Soil Science Institute, University of Hamburg, Federal Republic of Germany.

Special discriminating analyses established a system by which the water stability of aggregates can be derived from the analytical data commonly gathered in soil surveys. The system, now being tested on 200 soils in the Philippines,

14. Cumulative ammonia loss under different fertilizer management practices. Aguilar, Pangasinan, Philippines, 1986 dry season.



S. K. De Datta, reviewing the results of ammonia volatilization loss studies at Aguilar, Pangasinan, Philippines.



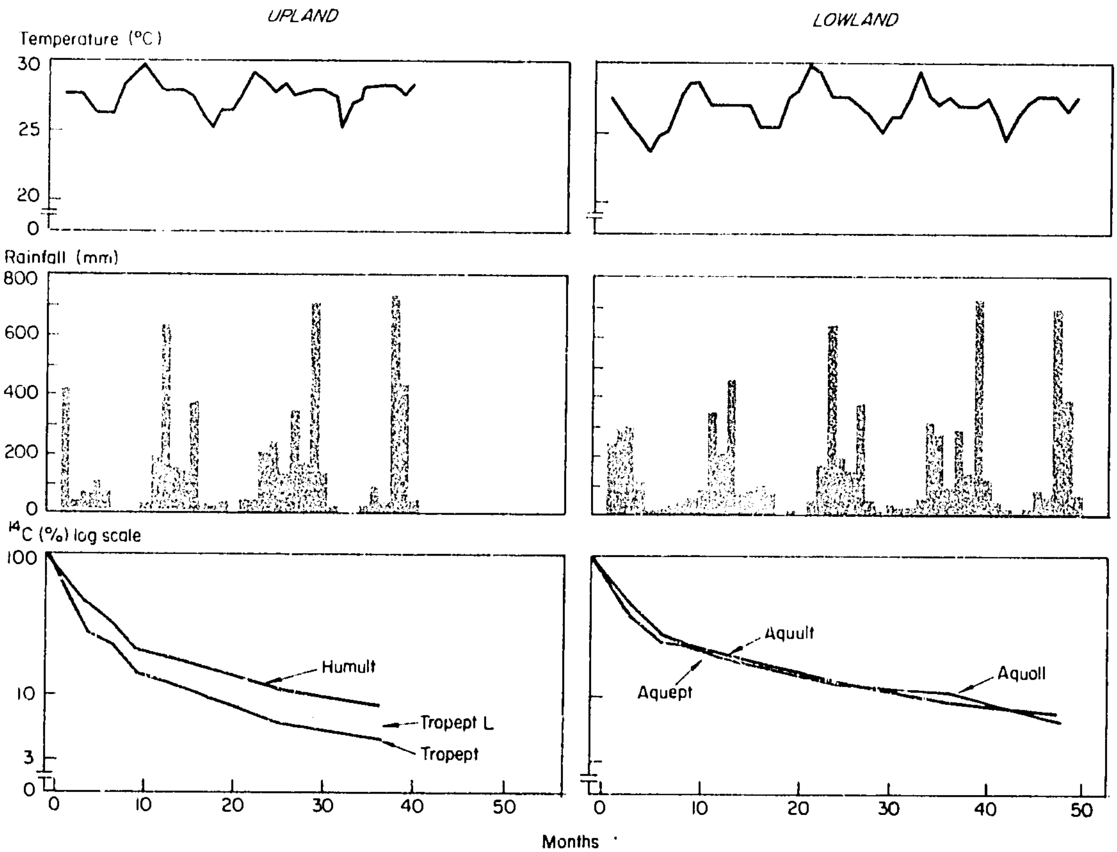
could be a simple tool for soil surveying and for mapping soil aggregation in puddled soils where data of routine chemical analyses are already available.

Evaluation of water retention curves in long-term experiments with different organic amendments indicates that organic matter is effective in increasing the water holding capacity as well as the porosity of the Tropaquepts and Haplaquolls tested.

Rice straw decomposition

We labeled rice straw with ^{14}C to measure its decomposition pattern in aerobic and submerged soils in collaboration with the Soil Science Institute, University of Hamburg.

In laboratory studies, mineralization rates were highly retarded under submergence. But in the field, mineralization was very rapid, regardless of water regime, and followed a logarithmic function in all soils. The decomposition of remaining, more resistant metabolites and residues is similar for all soils, with a half-life of about 2 years (Fig. 15).



15. Decomposition of ^{14}C-labelled rice straw in tropical upland soils and flooded tropical lowland soils. IRRI, 1986.

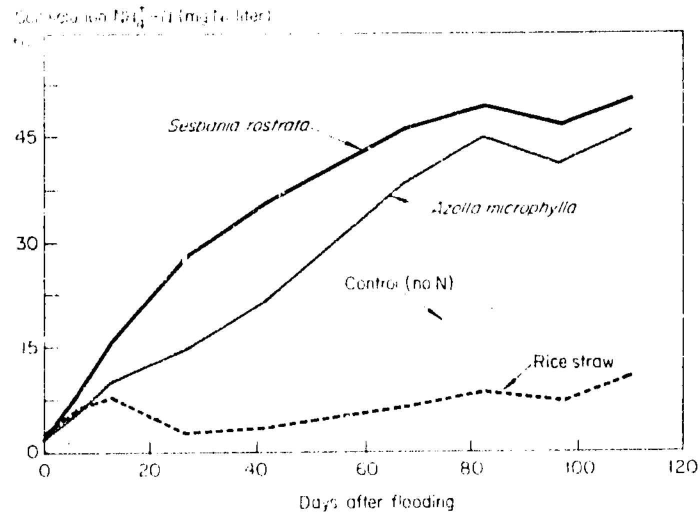
These results are in line with long-term studies at IRRI on the effect of water management in straw-amended plots.

Because of the rapid initial mineralization, application of organic substrates with a high carbon-to-nitrogen ratio, such as rice straw, depresses both exchangeable soil NH_4-N and soil solution NH_4^+-N. A visiting scientist from Sri Lanka studied the nutrient release patterns of azolla, sesbania, crotalaria, and cowpea green manures and rice straw. Unlike straw, green manure incorporation enhanced NH_4^+-N concentration in soil and soil solutions and increased rice yields (Fig. 16).

Effect of tillage on soil physical properties

Tillage studies at Sukamandi, Indonesia, of soybean following irrigated rice are paralleled by studies at Los Baños of mungbean following irrigated rice. Both soybean and mungbean following deepwater rice will be studied in An Giang, Vietnam. The studies have similar experimental designs and use similar procedures to measure soil-water and soil-strength variables.

For the Los Baños experiments, the IITA Program in grain-legume improvement is providing intensive evaluation of crop-water relations for promising cultivars and IFDC is helping with studies of soil-nitrate conservation by



16. Kinetics of soil solution NH_4^+-N in a flooded soil without a rice crop. Rice straw, azolla, and sesbania were incorporated at 116 kg N/ha. IRRI greenhouse, 1986.

weeds in legume - fallow - rice sequences. These studies are part of a larger collaboration with the University of Reading, England, that is examining water and nitrogen relationships in rice - legume cropping systems. Growth chamber studies are being done in England.

Special facilities at Consiglio Nazionale delle Ricerche, Pisa, Italy, used different implements and varying levels of puddling water and energy to measure Los Baños soil samples for the soil micromorphological effects of puddling.

New techniques of pneumatic fracture for measuring soil strength were applied to soil samples from Los Baños tillage experiments at the University of Minnesota, USA (Fig. 17).

The suitability of soil for dry tillage or puddling is influenced by the mechanical strength and stability of aggregates. The appropriateness of various rice soils for alternative forms of land preparation is being evaluated, using tests of aggregate stability developed for temperate-latitude soils from CSIRO, Australia.

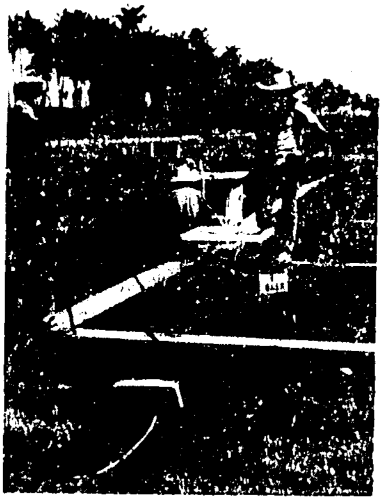
17. Soil suitability for flooded and for dry tillage is influenced by the mechanical strength and stability of aggregates. We studied rice soils and soils used for dry tillage of mungbean following rice, using newly developed sampling techniques.

The studies show that effective puddling can be achieved with lower inputs of puddling water and energy than farmers generally use, and that rice yields do not suffer with lower inputs. We determined that the minimum energy needed to decrease water infiltration to an acceptably low 1 mm/day was 3 kJ/m^2 ground area with plowing and 5 kJ/m^2 with rototilling.

A new floating rototiller was able to puddle a unit area of ricefield more quickly and conveniently than either a skid-supported rototiller or a plow and harrow. However, it was less effective in controlling weeds and it weakened a shallower zone of soil — a feature that could impair root and crop growth during periods when field submergence cannot be maintained.

Soil management in rice-based cropping systems

Methods for measuring physical variables in flooded rice soils have been developed by the National Research Institute of Agricultural Engineering (Japan) and the Universities of Ibaraki, Nihon, and Tsukuba. An English text authored by scientists from those institutions that describes these methods is in production at IRRI. Discussion forums are provided through soil scientists and agrohydrologists concerned with the physical aspects of soil management in rice-based cropping systems.



18. Field measurement of rice canopy photosynthesis. A transparent chamber is placed over the crop for less than a minute to monitor carbon dioxide uptake and vapor release of the plants. A portable generator makes the system mobile. IRRI, 1986.

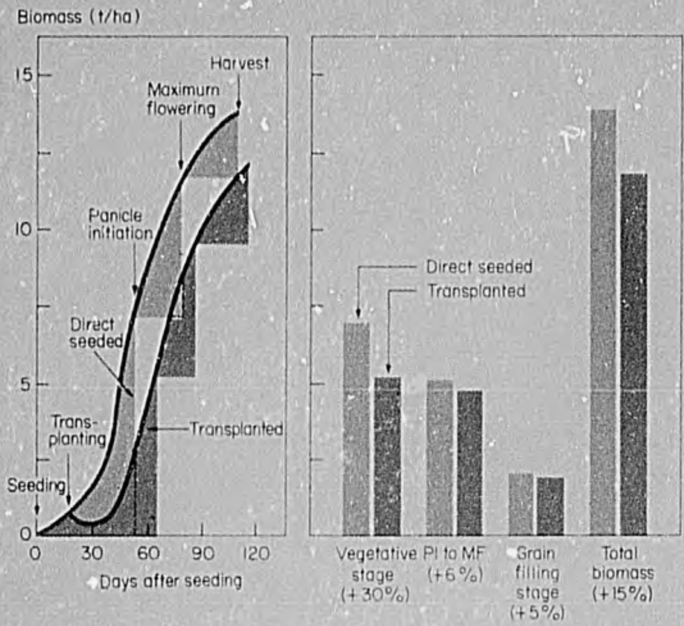
Monitoring canopy photosynthesis

We monitored canopy photosynthesis and night respiration in irrigated rice and used computer-modelling to detect constraints to light utilization and yield formation at different developmental stages of the crop in collaboration with the Botany Institute, University of Hamburg (Fig. 18).

In both wet and dry season studies, traditional transplanting caused severe physiological shock, strongly reducing tillering, and delaying crop development by 2 weeks. Dibble-seeded rice formed a closed canopy in a shorter time and produced more dry matter than transplanted rice (Fig. 19).

Recovery of symbiosis from endophyte-free azolla

The aquatic fern azolla is in symbiosis with nitrogen-fixing cyanobacteria *Anabaena azollae* Strasburger. Separation of

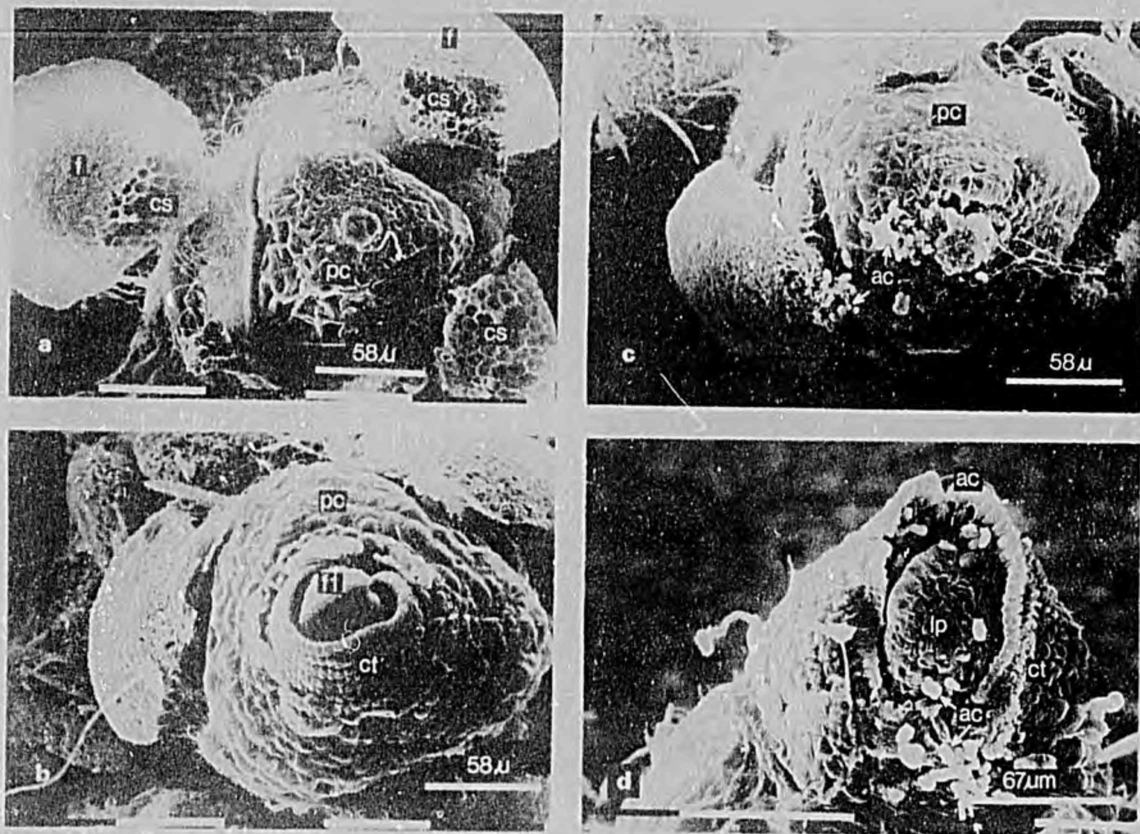


19. Growth patterns of dibble-seeded and transplanted IR64 monitored through cumulative canopy photosynthesis. Severe growth reduction at 30 days in transplanted rice was caused by transplanting shock. IRRI, 1986.

the *Azolla-Anabaena* complex into host and endophytic cyanobacteria has been reported, but not recovery of symbiosis in endophyte-free azolla.

We reconstructed symbiosis in *Anabaena*-free azolla *A. microphylla* or *A. filiculoides* by grafting the indusium containing *A. azolla* onto a fertilized megaspore apparatus (Fig. 20). The mature megasporocarps came from China. The endophytic *Anabaena* developed was able to fix N_2. It was identified by monoclonal antibody at the National Azolla Research Center, Fujian Academy of Agricultural Sciences.

The inoculation of laboratory-grown *Anabaena* isolates onto *Anabaena*-free azolla led to the colonization of *Anabaena* inside and outside the azolla leaf cavities. The *Anabaena* reacted positively against the fluorescent antibodies prepared from laboratory-grown *A. azollae* but negatively against fluorescent antibodies from symbiotic *Anabaena*. The azolla infected by laboratory-grown *A. azollae* failed to grow in a N-free medium.



20. Germination of fertilized azolla sporocarps. On the left, sporocarps without indusium — no *Anabaena* cells found; on the right, sporocarps to which indusium was grafted — *Anabaena* cells found.
a) Pericolumellar area (pc) of decapitated megaspore apparatus is pushed up by the developing embryo. Part of the float (f) shows the cut surface (cs). b) Sporeling at shooting stage. Cotyledon (ct), first leaf (fl). c) *Anabaena* cells (ac) on the center of pericolumellar area where sporeling is emerging. d) *Anabaena* cells attached to the surface of first developing leaf primordia (lp).

Blue-green algae

A better understanding of the ecology of blue-green algae in wetland ricefields would permit developing cultural practices that consistently maximize the contribution of photodependent N_2 fixation to the N_2 nutrition of rice. A senior scientist from the French Scientific Research Institute for Development (ORSTOM) has been researching free-living blue-green algae at IRRI since 1981.

Studies of the composition, productivity, and N available to rice have shown that N_2-fixing blue-green algae have a potential of about 30 kg N/ha per rice crop. Depending on the nature of the algal material and the application method, 15-36% of the blue-green algae N is available to the 2 crops following application. Limiting factors are P deficiency and invertebrate pests.

We have found that N_2-fixing blue-green algae are ubiquitous in rice soils. Their abundance correlates with soil pH and available P (Fig. 21). In most rice soils, indigenous N_2-fixing blue-green algae occur at densities much higher than can be brought about by inoculation with strains selected in the laboratory. Applying phosphorus, controlling grazer populations with organic pesticides, using deep-placed N, and inoculating with an inoculum produced from the indigenous soil had positive effects on N_2-fixing activity, surface accumulation of N, total plant weight, and grain weight.

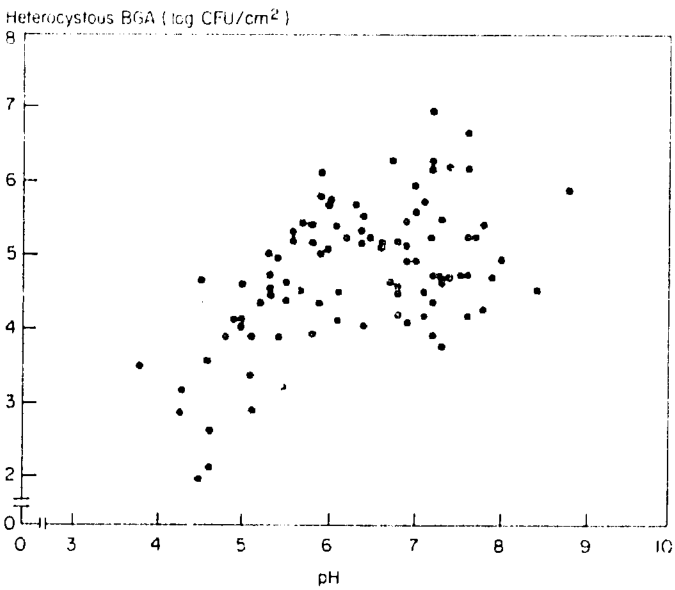
IRRI's blue-green algae collection now contains about 180 strains from 17 countries, most of them N_2-fixing strains isolated from ricefields.

Green manure crops

Research on stem-nodulating legume *Sesbania rostrata* has intensified, in collaboration with the University of Giessen, Germany, GTZ and CIRAD.

Systems analysis and simulation for rice production

Simulation models — simplified, mathematical representations of reality — are now much more accessible because of



21. Heterocystous blue green algae (log CFU/cm^2) in soils as a function of soil pH. Algal flora found in 130 ricefield soils from 6 countries contradicts the earlier belief that N_2-fixing blue-green algae are not present in many rice soils. N_2-fixing blue-green algae were found in all soils studied, at densities averaging 3×10^5 colony-forming units/cm^2 soil. Heterocystous blue-green algae correlated positively with pH, available P, and CEC.

the availability of personal computers. Models of crop production with no soil or biological contraints now help predict potential yields for new sites. Water status and the effect of water stress on crop growth can be simulated fairly well, particularly for a field with a deep soil water table. New models are being developed as knowledge of crop processes grows.

We have been collaborating with the Centre for Agrobiological Research, Wageningen, The Netherlands, in a training course on modeling and simulation of rice production. Basic materials were crop simulation models developed at Wageningen and rice crop data from IRRI.

Eight multidisciplinary teams of four scientists each from six countries and IRRI completed studies involving both a crop growth simulation model and crop growth validation research (Fig. 22). Some computed potential rice production in their own country, taking into account specific weather conditions and varietal characteristics. Others added soil water balance, to quantify the effect of intermittent drought on yield. Several studies concerned the damage caused by specified levels of biological constraints — yellow stem borer, leaf blast, weeds. One group studied the effect of nitrogen fertilizer on crop production.

22. Crop growth simulation modeling was studied by 32 scientists from 6 countries and IRRI at the Centre for Agrobiological Research, CABO, Wageningen, The Netherlands, as the first stage of a long-term cooperation. IRRI and collaborating countries are developing capacities to use simulation models in the application of basic research on physiological and ecological processes in applied and adaptive studies of upland and lowland rice.

In the second phase, IRRI will extend its capacity to use simulation models and systems analysis techniques and national institutes will develop their own infrastructures to effectively use basic research in country-specific models on the physiological and ecological processes of upland and lowland rice.

Increasing yields of short-duration varieties

Short-duration varieties usually have lower yields than medium-duration varieties. In collaboration with the Tropical Agriculture Research Center, Japan, we studied N level and spacing with six short-duration varieties and breeding lines. Low yields could be explained by less sink, which is attributed to less N in the plant at flowering.

This can be offset by closer plant spacing, resulting in maximum tiller numbers before panicle initiation. Panicle number type varieties are less responsive to cultural practices than are panicle weight or intermediate types.

Optimum growth duration and maximum yield may vary with cultural practices and soil fertility. When growth duration is shorter than optimum, yields decrease because of the small amount of differentiated sink caused by low N in the plant in the spikelet initiation stage. When growth duration is longer than optimum, yields decrease because of an increase in degenerated sink.

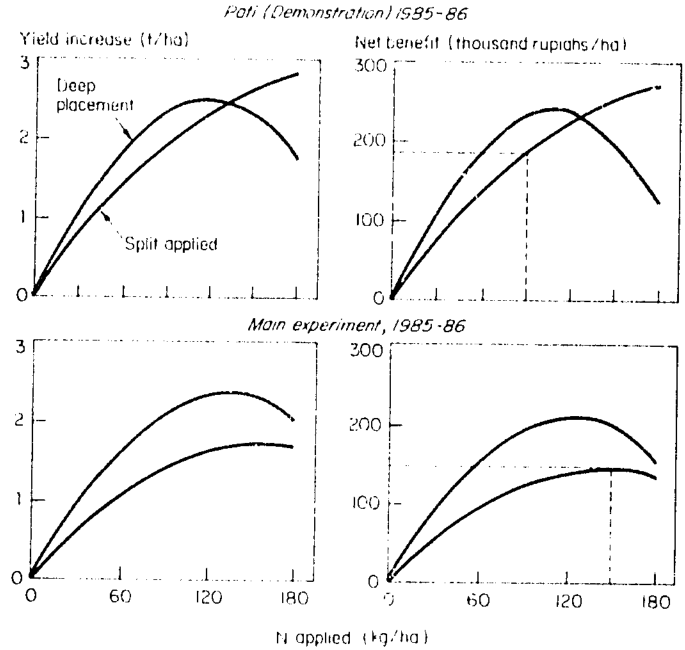
Maximum N efficiency in sink formation was observed in 125-day varieties at 20- × 20-cm spacing.

Farm-level fertilizer nitrogen efficiency

We evaluated the agronomic and economic feasibility of deep placement of N fertilizer in irrigated fields against standard practice and other improved practices. Deep placement of urea supergranules was as good as, and often better than, other practices.

The Center for Soil Research, Indonesia, has a pilot project in Java to evaluate the economics of urea supergranules and prilled urea over the long term. In 7 of 12 trials within 2 years, urea supergranules at 60 kg N/ha produced the same yield as prilled urea at 90 kg N/ha (Fig. 23).

In trials conducted by the Soil Fertility Division of the Thailand Department of Agriculture, deep N placement



23. Rice yield increase and net benefits from deep-placed urea supergranules and split applied prilled urea. Farm-level fertilizer efficiency trials, Pati, Central Java, Indonesia, 1985-86 wet season.

was superior. In a cooperative project with the Bangladesh Rice Research Institute, deep placement of 58 kg N/ha gave significantly higher yields than other fertilizer treatments and was similar to yields with 90 kg N/ha using split application.

Cooperative trials with the Philippine Ministry of Agriculture suggest that at 58 kg N/ha, deep placement has a potential advantage in some locations, but split application was just as efficient at most sites.

Grain quality

The major aroma principle in cooked milled rice of eight aromatic varieties from five countries has been identified as 2-acetyl-1-pyrroline through gas chromatography-mass spectrometry studies by flavor chemists at the USDA Western Regional Research Center, Albany, California. IRRI cereal chemists identified the rices. Pandan leaves commonly added during cooking to impart aroma contain the same chemical.

IRRI cereal chemists earlier found that hard gel consistency rices have harder cooked rices than those with soft to medium gel consistency. A cooperative study with starch chemists at Kagoshima University, Japan, demonstrated that the amyloses of hard gel consistency rices have properties similar to those of low-amylose Japanese rice starches.

High-amylose rices have been shown to have lower plasma glucose and insulin response than waxy, low-amylose, and intermediate-amylose rices. Estimates by nutritionists at the University of Toronto of the glycemic index of three high-amylose rices differing in gel and Amylograph consistency at the gelatinization temperatures used in processed rice products, parboiled rice, and rice noodles suggest that low gelatinization temperature rices have higher glycemic index than intermediate ones. The major factor seems to be shorter cooking time. Processed rice products also tend to have lower glycemic indexes than milled rice.

Feed quality of straw

The ruminant feed quality of the straw of IRRI varieties is being studied in cooperation with animal scientists at the Institute of Animal Science, UPLB, and the University of Melbourne and LaTrobe University, Australia. Varietal screening of both high-yielding and traditional varieties also has been done with the Animal Feeds Section, TDRI, London. Dry matter and organic matter digestibilities differed between wet and dry season crops, suggesting a significant effect of environment on the feed value of rice straw.

Upland crops for rice-based farming systems

The most important upland crops grown before and after rice are mungbean, soybean, cowpea, maize, peanut, and sorghum. We collaborate with national programs and other international centers to identify varieties suitable for rice farming systems.

In 1986, we evaluated 266 advanced cowpea breeding lines from IITA for environmental adaptability, disease resistance, and yield performance. Several short- and medium-duration lines were superior.

Of 240 soybean lines tested for adaptability, disease resistance, maturity, and yield performance, 42 were advanced for yield tests. We also evaluated 16 each short-, medium-, and long-duration cultivars for yield performance and seed storability.

In collaboration with the Philippine Institute of Plant Breeding (IPB), we evaluated 3,715 mungbean cultivars for planting after rice; 44 lines from the Asian Vegetable Research and Development Center (AVRDC) were highly resistant to powdery mildew.

An observational nursery of 1,323 peanut cultivars from IPB and International Soybean Program (INTSOY) was planted following rice at UPLB and Pangasinan State University: 99 were selected for preliminary yield trials and 5 were included in the Asian Rice Farming Systems Network.

Observational nurseries of INTSOY soybean cultivars in wet and dry seasons looked for high nitrogen fixation, tolerance for acidity rust and Cercospora leaf spot, and large seededness with high yield.

We evaluated ICRISAT sorghum varieties and hybrids during the dry season and pigeonpea varieties after lowland rice under zero tillage. We also screened legumes for acid tolerance in collaborative research with the Indonesian Sukarami Research Institute for Food Crops (SARIF).

In collaborative research with the Philippine IPB and the Thailand Field Research Institute on drought-tolerant soybean lines, we evaluated cultivars under line-source irrigation gradient. Medium-duration (85-90 d) cultivars performed best; short-duration lines had low yields, long-duration lines either had low yields or did not show any yield advantage.

STRATEGIC RESEARCH COOPERATIVES

ncreasingly, the accelerating needs for new knowledge about rice demand that research be carried out at epicenters of stress or across the varied environments in which a problem occurs. Sophisticated research equipment and the costs of high technology research also impel reciprocal cooperation.

New forms of partnership are developing. Some provide pathways for utilizing the resources of more than one international or regional research program, others enable developing countries to collaborate across geographical and political boundaries. These multilateral scientist and institutional linkages are a new strength in meeting the new challenges.

Early work directed mainly to irrigated rice was done mostly in the Philippines. As we shift our emphasis toward less favorable rice environments, much of our research is being undertaken jointly with national programs where the particular rice environment or stress situation is found.

This approach includes developing a coordinated global research program to accelerate progress in raising and stabilizing rice yields.

The emphasis is on a particular environment or on a megaproduction system, in research designed to serve two or more countries with similar agroclimatic conditions.

Rainfed lowland rice

Rice is grown on about 30 million hectares of rainfed lowlands in South and Southeast Asia. The most extensive areas are concentrated in the belt stretching from eastern India and Nepal through Bangladesh and Burma to Thailand, Laos, Kampuchea, and Vietnam. Strong links with national research programs are essential in our strategies to improve rainfed rice yields.

Traditional rainfed varieties are tall and photoperiod sensitive, ensuring reasonable yield stability under unpredictable weather conditions. Improved rices should give higher yields while maintaining as much of that stability as possible. Such traits as tolerance for drought, flooding, and adverse soils that are being incorporated into intermediate height breeding lines should provide valuable germplasm to breeders in national programs. Because crop management is critical to obtaining higher yields with improved rainfed rices, agronomic studies go hand in hand with varietal improvement (Fig. 24).

Our program in Thailand to improve rainfed rice yields in a drought- and submergence-prone environment illustrates the collaboration that this work demands. Almost half of Thailand's rice area is in the northeast, the most

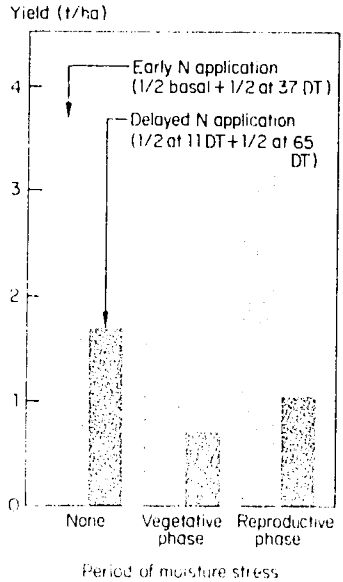
24. Thai and IRRI breeders make plant selections in rainfed lowland F_2 nurseries at 6 locations in Northeast Thailand.

economically disadvantaged region of the country. Soils are generally coarse and highly infertile, rainfall is low and unpredictable, and rice yields are low (1.3 t/ha).

Improved rices that can replace the tall, low-yielding local varieties must be photoperiod sensitive and drought tolerant. Crosses of Thai varieties and IRRI breeding lines with improved yield and disease and insect resistance are being grown each rainy season at six northeast Thailand research stations. Thai and IRRI breeders make the F_2 selections in the wet season and bring the seed to IRRI to plant during the dry season for a generation advance and screening. This year, we identified some promising lines for testing.

Crop management studies have focused on varietal response to inputs and crop establishment. In previous studies, response to fertilizer was extremely low. With a green manure crop, such as *Sesbania rostrata*, response to fertilizer increased. Because early crop establishment is essential to avoid drought and submergence, we are studying direct seeding methods which could allow farmers to establish their rainfed rice crop before those stresses occur, for a crop in years when water shortages make it impossible to transplant.

Our research shows clear advantages to early N applications in drought prone rainfed areas. Early N appeared to improve plant vigor, enabling the crop to better withstand moisture stress during vegetative and reproductive phases (Fig. 25).



25. Effect of N timing and moisture stress on grain yield of rainfed lowland rice with 80 kg N/ha. IRRI, 1986. DT = days after transplanting

Upland rice

About two-thirds of the world's upland rice is grown under unfavorable environments. In a survey on upland rice, researchers identified four major constraints: poor soils, mostly low P and depleted major elements; blast, particularly neck blast; drought at different times during the growing season, and weeds.

Because the problems are similar around the world, a cooperative of upland rice breeders has been started. These scientists are exchanging materials, information, visits, and research results about breeding materials in diverse difficult conditions. The group includes SARIF in Indonesia, Centro Nacional de Pesquisa-Arroz Feijão in Brazil, Institut des Savanes in West Africa, the University of Chiang Mai, Thailand, and West Bengal, India, with support from CIAT, IITA, WARDA, IRAT, and IRRI.

In 1986, promising lines and varieties chosen for their adaptability to poor soils, blast resistance and drought tolerance, and good vegetative vigor were exchanged.

In West Bengal, breeders selected several IR entries that showed better drought tolerance than the local checks (Fig. 26). At Villavicencio, Colombia, 73 progenies from IRRI and NARS were selected for adaptability to poor soils and blast resistance (Fig. 27). At IRRI, about 140 entries were selected from the more than 600 screened.

Problem soils

Most rainfed ricelands suffer from mineral deficiencies, toxicities, and imbalances. Some irrigated lands, such as the sodic soil areas of India and Pakistan, also have such soil

F_4	Parents	Group	Maturity	Yield (g)	Fertility (%)
IR46787-10	IRAT 104/Salumpikit	6/1	93	135	72
IR47687-33	IRAT 104/Salumpikit	6/1	92	68	38
IR47688-35	IRAT 112/Sein Talay	6/1	91	102	50
IR47697-2	ITA 235/IR9669	6/1	91	85	70
IR47699-22	ITA 235/Palawan	*6/6*	*87*	*140*	*67*
IR47699-28	ITA 235/Palawan	*6/6*	*89*	*115*	*55*
IR47701-20	ITA 235/UPLRi-7	6/1	80	94	65
IR47705-6	Moroberekan/Palawan	*6/6*	*89*	*100*	*71*
IR47721-21	IRAT 177/Boewani	6/1	89	113	55
IR47724-14	Moroberekan/IRAT 177	*6/6*	*90*	*140*	*47*
IR47730-4	IRAT 112/Apura	*6/1*	86	92	60
Dular	(local check)	2	85	81	32
Panke	(local check)	2	100	123	9
Soni	(local check)	2	82	65	43

Maturity = seed to seed duration in days
Group = electrophoresis data

26. Performance of IR upland varieties under severe drought at heading in West Bengal, India, 1986 wet season.

stresses as salinity, excess Na, and Zn deficiency. In South and Southeast Asia alone, about 23 million hectares of adverse soils could be used for rice cultivation if tolerant varieties and management practices were available.

The complexity and location specificity of adverse soils demand that varietal improvement research be carried out in target environments. Bangladesh, India, Indonesia, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam

27. Performance of IR upland varieties in poor soils and with severe blast incidence in the llanos, Colombia, 1986 wet season.

Selected lines[a]	Parents
IR47686-4-2	IRAT104/Palawan
IRIR47686-7-1	IRAT104/Palawan
IR47686-7-2	IRAT104/Palawan
IR47686-8-4	IRAT104/Palawan
IR47686-10-2	IRAT104/Palawan
IR47686-12-3	IRAT104/Palawan
IR47686-13-2	IRAT104/Palawan
IR47686-C-13-2	IRAT104/Palawan
IR47686-13-3	IRAT104/Palawan
IR47691-9-7	IRAT140/Palawan
IR47691-48-5	IRAT140/Palawan
IR47698-16-4	ITA 235/Kinandang Patong
IR47698-16-5	ITA 235/Kinandang Patong

[a]All fall under the 6/6 group electrophoresis data.

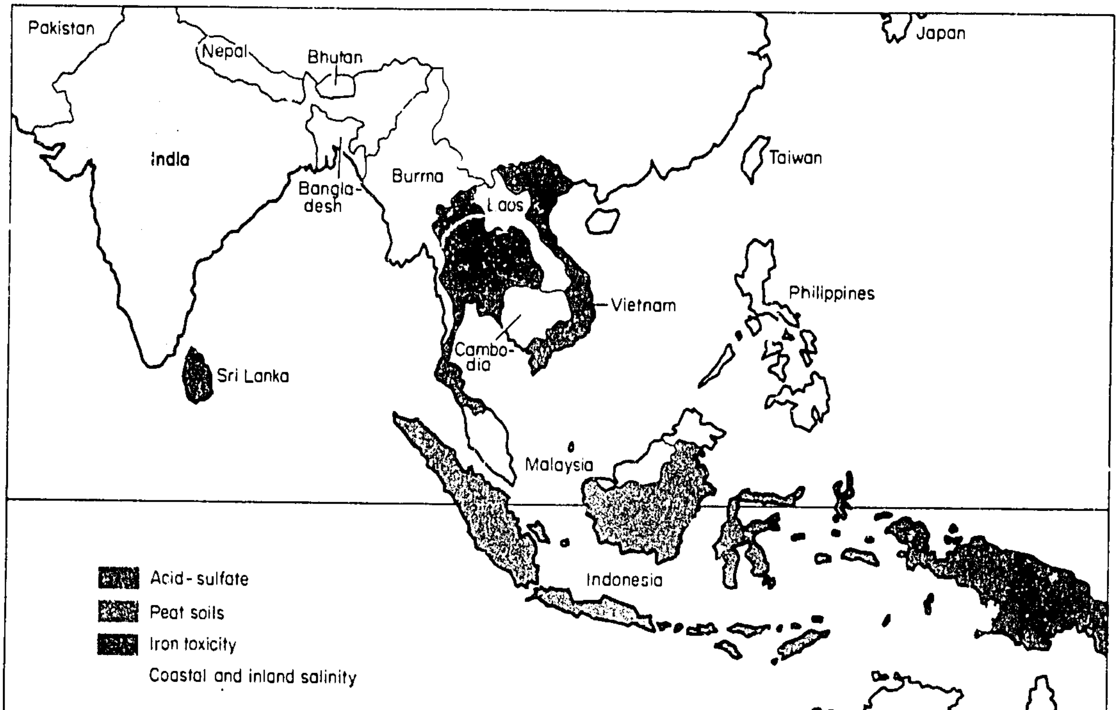
participated in a workshop to review the status and needs of varietal improvement research. The inability of national programs to conduct prebreeding research is a serious constraint.

To conduct prebreeding research, IRRI is collaborating in a research cooperative with national programs selected for each adverse soil type (Fig. 28). We also will organize shuttle breeding, rapid generation advance methods, and germplasm exchange.

Deep water rice

One problem that breeders of deep water rice face is the location — specific diversity of needed traits. Areas that face sudden rises in floodwater need submergence-tolerant rices. Areas where floodwaters rise slowly need rices that can elongate their stems.

Depending on the location, harvest dates can spread from late October to beyond December. Areas vary in their need for short-duration, long-duration, and photoperiod-



28. Within the problem soil research cooperative, India will conduct prebreeding research for coastal and inland salinity, Thailand and Vietnam for acid-sulfate conditions, Indonesia for peat soils, and Sri Lanka for Fe toxicity.

sensitive varieties. The regional program on deep water rice is based in Thailand, but involves collaboration among Bangladesh, Burma, and Vietnam, which have significant deep water areas.

Wide variability must be available for breeders to select deep water rices for specific environments. The International Deep Water Rice Observational Nursery (IRDWON) has made useful materials available, but these are rarely suitable for immediate release in a specific locality.

The limiting factor is sufficient initial variability. IRRI makes some 600 new deep water crosses a year, often utilizing established varieties and outstanding IRDWON entries as parents. In slightly more than a year, some 300 F_2 hybrid populations have been provided to national rice breeding programs.

Several deep water rices introduced by Banjarmasin Research Institute for Food Crops (BARIF) through the International Rice Testing Program were grown in farmers' field trials in the river backswamps north of Banjarmasin during the October-April season, when the water gradually rises, then stagnates. This additional deep water rice crop complements the normal rice crop, which is transplanted in sequence with receding water from May to October.

Earlier introductions in the rising-water regime had demonstrated good survivability.

Hybrid rice

IRRI and China have been working collaboratively for 7 years to develop suitable F_1 hybrids. We supply parental lines possessing short growth duration, good grain quality, and multiple disease and insect resistance. Now we are exploring the potentials and problems of using this technology to increase rice yields in countries outside China. A technical cooperative on hybrid rice is being coordinated by Hunan Hybrid Rice Research Center and IRRI.

Some 220 delegates and observers from 17 countries attended the first International Symposium on Hybrid Rice at Changsha, Hunan, China, 6-10 Oct 1986 (Fig. 29). Nine technical sessions covered aspects of hybrid rice production, with particular emphasis on heterosis, male sterility and

29. Participants in the 1986 International Symposium on Hybrid Rice visited hybrid rice experiments at Changsha, Hunan, China.

fertility restoration, outcrossing mechanisms and hybrid seed production, breeding procedures, disease and insect resistance, grain quality, cultural management, and physiological and genetic research.

Effect of female to male row ratio on outcrossing rate and hybrid seed yield

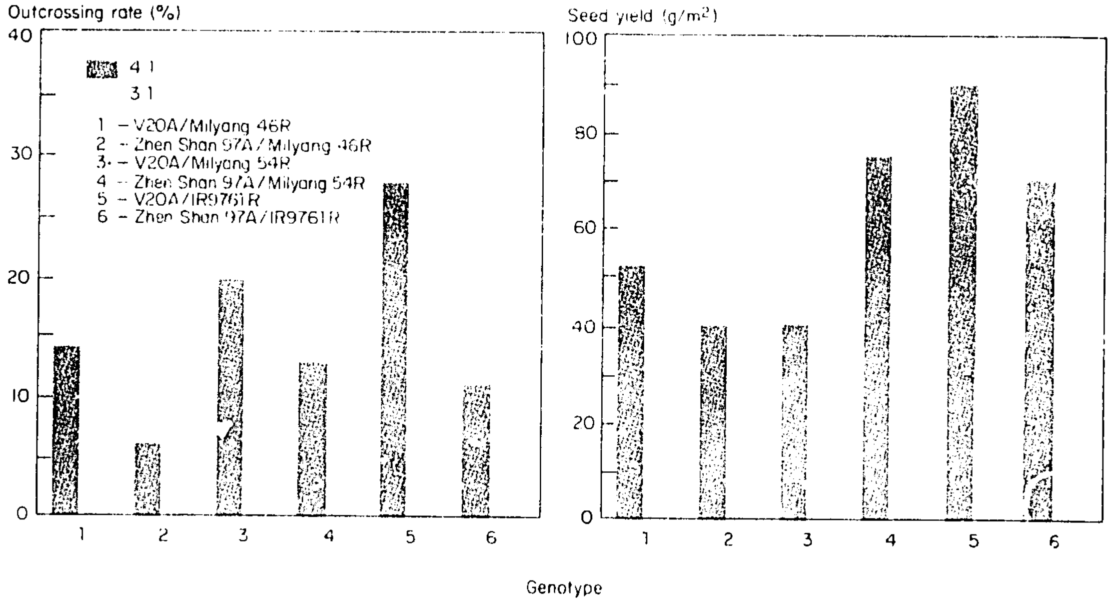
A cooperative trial at Suweon, Korea, studied the effect of female to male row ratios on outcrossing rate and seed yield of two cms lines, V20A and Zhen Shan 97A. Zhen Shan 97A flowering synchronized with that of the restorer lines (Milyang 46R, Milyang 54R, and IR9761-19-1R) used in the study. V20A flowering did not synchronize as well with restorer lines Milyang 46R and Milyang 54R.

The female to male row ratios 4:1 and 3:1 gave higher outcrossing rates and seed yields. The 6.3-18.5% outcrossing rate on ms line 97A resulted in a hybrid seed yield of 29.1-76.1 g/m^2. V20A showed an outcrossing rate of 6.6-38.6%, yielding 29.7-90.8 g/m^2.

The highest seed yield (90.8 g/m^2) was in V20A/IR9761R, with a row ratio of 4:1 (Fig. 30).

Rice genetics cooperative

The Rice Genetics Cooperative established during the International Genetics Symposium held at IRRI in May 1985 has as its major aim fostering cooperative research on all aspects of rice genetics. Its secretariat is at



30. Outcrossing rate, and seed yield of different female to male row ratios in cytoplasmic male sterile lines V20A and Zhen Shan 97A. Suweon, Korea 1986.

IRRI; its 15-member coordinating committee is supported by 4 standing committees.

The committee on gene symbolization has prepared a set of rules for symbolizing marker genes and for numbering chromosomes. The committee on genetic stocks has established two centers: at IRRI and at Kyushu University, Japan. The committee on genetic engineering has compiled a list of possible DNA vectors. The Rice Genetics Newsletter Vol. 3 was published in December 1986. The second International Rice Genetics Symposium will be held at IRRI in 1990.

Upstream-downstream network

Rockefeller Foundation is funding an upstream-downstream research network to promote the application of such emerging biotechnology techniques as anther culture, somatic cell culture, and genetic engineering to rice improvement. Our participation links IRRI with laboratories in several developed and developing countries.

Integrated pest management

IRRI is working with a Food and Agriculture Organization-sponsored Integrated Pest Management in Rice project for

Asia to establish pest population thresholds and to train extension field staff in the integrated pest management (IPM) concepts of pest control methods. Each region will need a localized set of IPM practices. With verified IPM technology for each environment and region, farmers can be trained to apply the technology to maximize profits and stabilize yields.

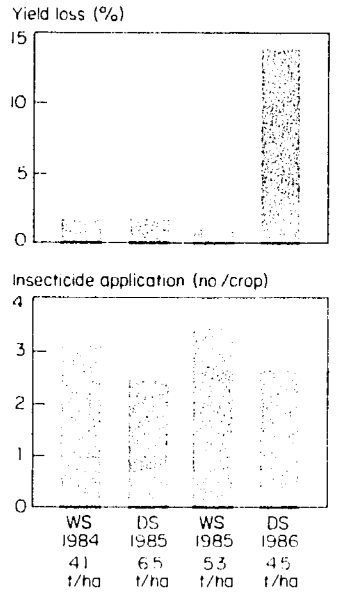
Pesticide-susceptibility monitoring

A project to monitor the susceptibility of rice insect pests to different insecticides involves India, Sri Lanka, Bangladesh, Thailand, Vietnam, Malaysia, Indonesia, Philippines, China and Taipei, Korea, and Japan. The 14 national program scientists hope to standardize methods of determining susceptibility and to monitor baseline susceptibility of stem borers, planthoppers, and leaffolders to eight insecticides.

Increased insecticide applications do not increase yield

In Laguna, Philippines, 90% of the irrigated lowland rice area is planted to high yielding varieties, with yields averaging 4.6 t/ha per crop in the wet and dry seasons. Crops receive 55-90 kg N/ha and most farmers use herbicides plus rotary weeders to control weeds.

To control insects, more than 95% of the rice farmers spray each crop 2 to 4 times. But yield losses attributable to insect pests were found to be less than 2% in 3 out of 4 pest-resistant varieties harvested (Fig. 31).



31. Yield losses in farmers' fields sprayed and not sprayed with insecticide. Farmers were interviewed each month during the cropping season about their insecticide application. Yield losses were the difference between plots receiving insecticide applications and those not sprayed. Laguna, Philippines, 1986.

GLOBAL RESEARCH NETWORKS

etworks are a central factor in IRRI and national program collaboration and in cooperation among countries and national and international institutions. We initiated international networks more than a decade ago to accelerate the development and diffusion of technology.

In the broadest sense, networks link individuals and institutions with shared purposes and focus. Our networks link the international centers with national program scientists and institutions working toward similar goals. Through participation in networks, national programs broaden their resource and information bases by sharing technology, knowledge, and experience with IRRI and with each other.

THE NETWORKS

- *International Rice Testing Program — a mechanism for the exchange among scientists in different countries of elite rice germplasm, to be evaluated and utilized in their own specific environments.*
- *International Network on Soil Fertility and Fertilizer Evaluation for Rice — a collaborative effort aimed at increasing fertilizer use efficiency and at improving and maintaining the fertility of rice soils through integrated nutrient management.*
- *Asian Rice Farming Systems Network — an approach for identifying more productive rice-based farming systems, particularly for small-scale farmers in the different countries of Asia.*

The networks coordinated at IRRI link closely with our central research thrusts and are an effective mechanism for collaboration in research, training, and information transfer among scientists all over the world. They operate similarly:

- Exchange information to facilitate the sharing of ideas, methodologies, and research results.
- Provide scientific consultation through regular meetings of the scientists from participating countries to plan research activities and to analyze results.
- Undertake collaborative research, in which participating countries jointly plan, implement, monitor, and share results. They often follow a common research format to simplify data comparisons.
- Organize site tours for network participants to review experiments and varietal performance in the field.

International Rice Testing Program

IRTP links more than 300 rice research stations, institutes, and universities in more than 70 countries in Asia, Africa, Latin America, and Europe. It is the basis of international cooperation in rice varietal improvement. In 1986, 24 types of nurseries were composed and 1,466 nursery sets were distributed to 52 countries; 69 promising lines were identified for adaptability to different rice environments and for tolerance for various stresses (Fig. 32).

Two monitoring tours in 1986 focused on cold-tolerant rice and varietal resistances to diseases and insects; 35 scientists participated and provided input for future plans of work through continuing collaboration.

The cold tolerance monitoring tour visited Hungary, Nepal, Pakistan, India, and Korea. The final workshop on the status of rice improvement in low temperature areas was held in Suweon, Korea.

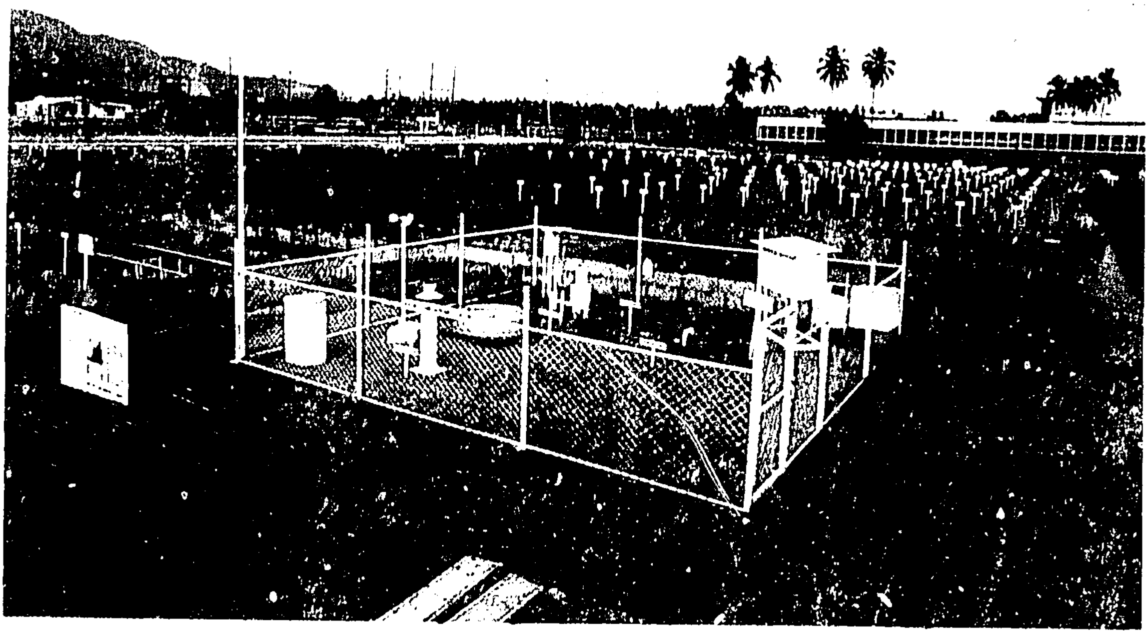
Rice weather studies were conducted at 22 sites in 16 countries within the IRTP network that represent wide

Nursery	Entries
IRRIGATED	
IRYN (Very Early)	IR50, IR25924-51-2-3, IR32429-47-3-2-2, UPR103-80-1-2
IRYN (Early)	Chianung sen yu 26, KAU1727, C662083, IR13240-108-2-2-3, Si-pi 692033, IR36
IRYN (Medium)	BG380-2, BR153-2B-10-1-3, IR21820-154-3-2-2-3, IR28118-138-2-3
RAINFED LOWLAND	
IRRSWYN (Early)	IR21567-9-2-2-3-1-3, IR21178-39-P1, CR213-1002, IR21188-87-3-3-2-2, IR28941-164-1-5, IR4829-89-2
IRRSWYN (Medium)	OR142-99, RP1045-25-2-1, BR51-74-6-J1, RP975-109-2, BR11, IR9884-54-3-1E-P1
UPLAND	
IURYN (Early)	BG367-4, HPU741, IR10198-66-2, IR19793-25-2-2, IR9729-67-3, IR9761-19-1
IURYN (Medium)	B2997C-Tb-60-3-3, B3623g-Tb-49, IR12979-24-1, UPL Ri 7, B3622e-Tb-5-4-4, IR10781-75-3-2-2
LOW TEMPERATURE	
IRCTN	Ouella Inia, Barkat (K78-13), IR19746-26-2-3, IR9202-6-1-1, Lien-chan-Ze-Thou
SALINITY	
IRSATON	Pokkali, IR10198-66-2, Bhurarata-4-10
DISEASES	
IRBN (Blast)	Tetep, Huan-sen-goo, Ta-poo-cho-z, SR3044-78-3, IRAT109, IRAT13, IRAT34, IRAT147
IRBBN (Bacterial blight)	RP633-76-1, IR54, DV85, IR26717-1-1-2-1-1
INSECTS	
IRBPHN (Brown planthopper)	PTB33, Rathu Heenati, BG367-2, IR13540-56-3-2-1, IR27325-111-2-1, Sinna Sivappu
IRWBPHN (White-backed planthopper)	IR13475-7-3-2, IR2035-117-3, IR15527-21-2-3, Sufaida 172, W1240

32. Entries performing well in the 1985 IRTP nurseries.

variation in climatic environment but with minimal soil problems during a 20-month study in 1985-86; 65 trials were completed. Data on daily rainfall, temperature, humidity, radiation, and windspeed, as well as detailed information on phenological stages, yield, and yield components of 10 genotypes of rice, were gathered (Fig. 33).

Solar radiation and temperature are believed to be the major environmental factors affecting yields in these trials. A predictor model developed from these data is based on five weather variables: preflowering day-night temperature difference, preflowering daytime temperature, sum of



33. On-site monitoring of weather variables was standardized for the rice weather studies. The equipment at IRRI was duplicated at all 22 sites to gather standardized data on temperature, rainfall, and global radiation.

preflowering radiation, sum of postflowering radiation, and postflowering night temperature. It predicted actual yields within 0.5 t/ha for more than half the trial data used.

The Caribbean Rice Research Network (CRRN), initiated in February 1986, is sponsored by IRRI IRTP/United Nations Development Programme and CIAT-Canadian International Development Agency/International Development Research Centre (IDRC). The Secretaria de Estado de Agricultura of the Dominican Republic is providing logistical support and facilities.

CRRN expects to contribute to the development of rice varieties suitable for the environmental and economic conditions in cooperating countries. Belize, Dominican Republic, Haiti, Jamaica, Trinidad and Tobago, Guyana, and Surinam are participating in the regional program.

In 1986, IRTP nurseries from IRRI and CIAT were evaluated at CEDIA-Juma and several lines were selected for the first observational nursery. Production environments were defined (Fig. 34).

34. Rice production environments in Caribbean countries.

Environment	Countries
IRRIGATED	
Favorable temperature Fertile soils Problems: fungus diseases, hoja blanca vector	Belize, Cuba, Jamaica, Gynana, Trinidad, Dominican Republic, Surinam
Favorable temperature Moderately acid soils Problems: Fe tox., fungus dis., hoja blanca vector	Belize, Dominican Republic, Trinidad, Surinam
Unfavorable temperature Fertile acid soils Problems: low temperature, fungus disease, hoja blanca vector	Cuba, Dominican Republic
Favorable temperature- Neutral/alkaline soils Problems: salinity, fungus diseases, hoja blanca vector	Cuba, Guyana, Jamaica, Haiti, Dominican Republic, Trinidad
Favorable temperature- organic soils Problems: nutritionals, fungus diseases, hoja blanca vector	Surinam, Jamaica, Dominican Republic
RAINFED LOWLAND	
Shallow Problems: floodings, fungus diseases, Fe toxicity, hoja blanca-vector	Jamaica, Dominican Republic, Trinidad and Tobago
UPLAND	
Moderately favorable Problems: fungus diseases, hoja blanca vector, short droughts	Belize, Guyana, Haiti, Trinidad and Tobago
Acid soils-(savanna) Problems: nutritonals, fungus diseases, hoja blanca vector	Belize, Guyana
Traditional Problems: blast, brown spot, drought stress	Belize, Haiti, Dominican Republic, Trinidad and Tobago

The first advisory committee for CRRN met in Nov 1986 at Juma, Dominican Republic, to develop plans for regional rice testing and research. IRTP-Latin America has its own advisory committee with the program jointly coordinated by IRRI/CIAT from CIAT headquarters in Cali, Colombia.

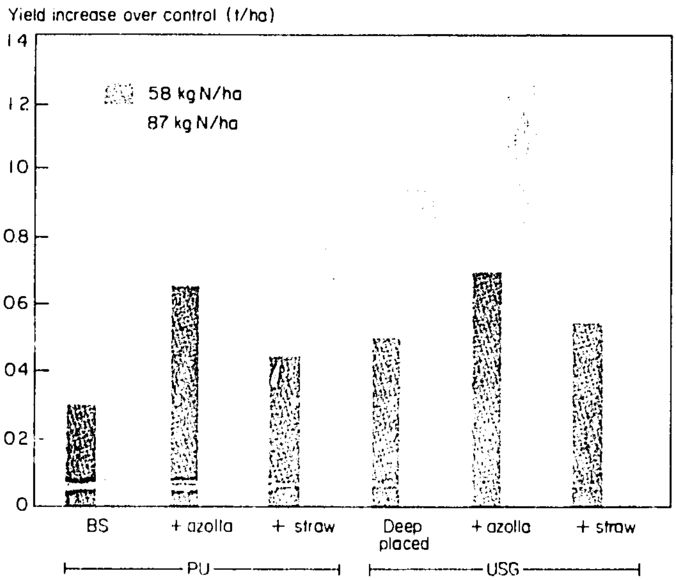
IRTP-Africa was initiated in 1985 to increase the focus on region-specific needs for improved varieties for different environments in Africa. The regional IRTP is administered through collaboration with IITA, WARDA, and national programs on that continent. IRTP-Africa has its own advisory committee. Headquarters are at IITA in Nigeria with joint coordination by the IRRI liaison scientist and an IITA scientist.

IRTP in West Africa is coordinated by WARDA from its headquarters in Monrovia, Liberia. IRTP in East Africa is coordinated by an IRRI scientist assigned at Morogoro, Tanzania. The advisory committee for IRTP-Africa met in March 1986 at Arusha, Tanzania, to develop plans for the rice testing Program for Africa.

International Network on Soil Fertility and Fertilizer Evaluation for Rice

Through INSFFER, 57 rice scientists in 22 countries on 3 continents collaborate in research trials, training courses, site tours, and workshops. Integrated nutrient management is a major research focus; 12 collaborative trials are being conducted now.

Inorganic N fertilizers applied alone or in combination with azolla or fresh straw were evaluated in 22 trials at 9



35. Average yield increases in irrigated lowland rice with prilled urea (PU) and urea supergranules (USG) alone and with azolla and straw. First international trial on integrated inorganic and organic N fertilizer in irrigated rice. Average of 2 trials, Wanli, China, 1984-85.

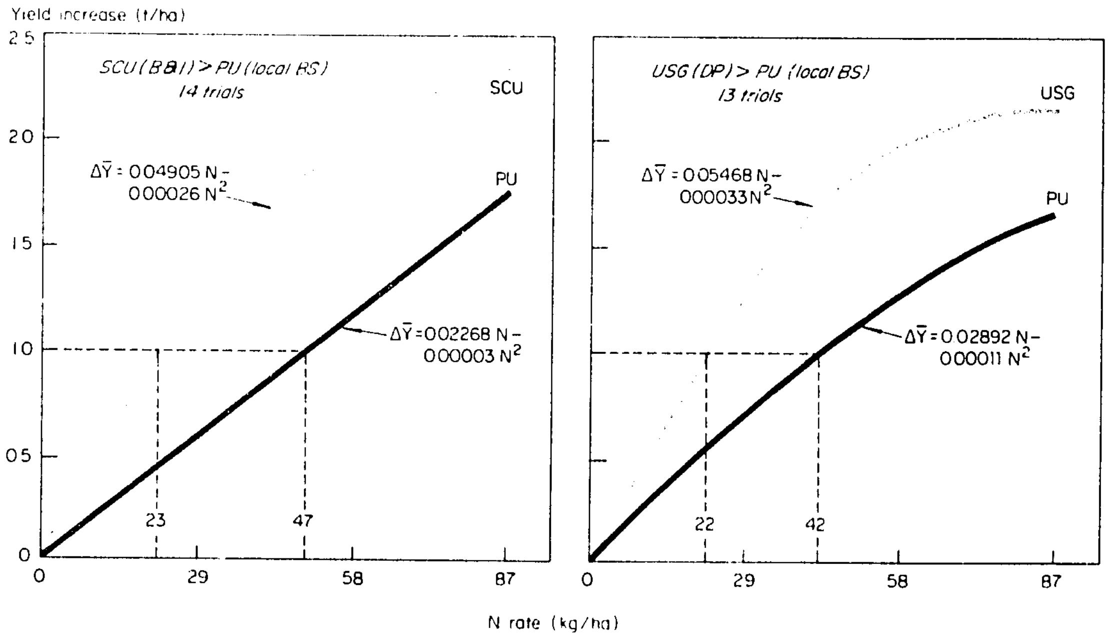
lowland sites in China, Bangladesh, India, and the Philippines. Yields with azolla plus prilled urea or urea supergranule equaled yields with inorganic sources alone, in Wanli, China, they were higher (Fig. 35).

Trials at 24 irrigated sites in 7 countries compared deep-placed urea supergranules and broadcast and incorporated sulfur-coated urea with local best split and standard best split application of prilled urea. Both sulfur-coated urea broadcast and incorporated and urea supergranules deep-placed were significantly better than prilled urea. In an analysis using a multifertilizer response model and the fertilizer test model, 51% less N was required to obtain an initial yield increase of 1 t/ha if N was applied as sulfur-coated urea instead of prilled urea; 48% less N was needed if applied as urea supergranules (Fig. 36).

The potential for deep-placement urea supergranules is promising. India, Indonesia, and Thailand are conducting multilocation farm trials now.

In rainfed trials at 31 sites in 9 countries, yield increases in response to sulfur-coated urea broadcast and incorporated and urea supergranules deep-placed were significantly higher than to prilled urea in 33% of the trials.

36. Response of irrigated rice to sulfur-coated urea (SCU), urea supergranules (USG), and prilled urea (PU). Sixth international trial on N efficiency, 1984-85. DP = deep placed, BS = best split, B&I = broadcast and incorporated.



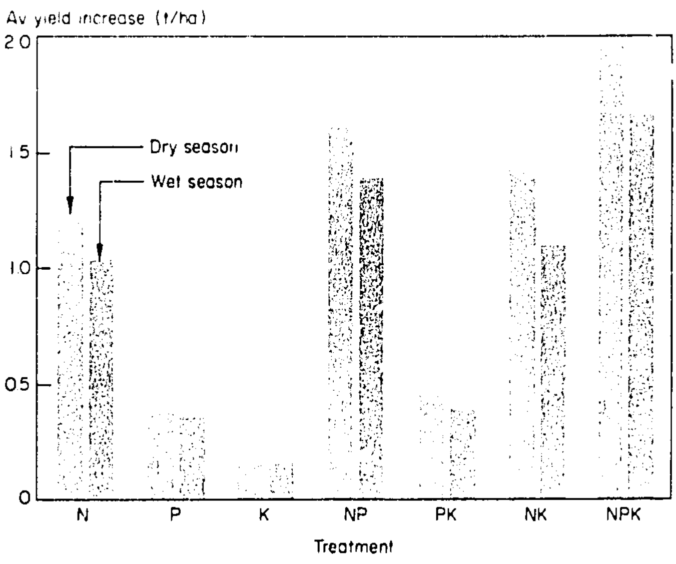
An initial yield increase of 1 t/ha required 57% less N applied as sulfur-coated urea and 62% less N applied as urea supergranules.

Hand-placed urea supergranules gave the highest yields in both rainy and dry seasons in 15 trials comparing hand and machine placement. In the dry season, machine-applied urea supergranules resulted in higher yields than machine-applied prilled urea. Preliminary findings suggest that machine application may be improved further.

Combining azolla with inorganic fertilizer resulted in yields similar to those with inorganic fertilizer alone. Incorporating azolla crops before and after transplanting can substitute for as much as 60 kg N/ha.

Continuous trials on the sustainability of yield are underway on 10 sites in 4 countries. N continues to be the limiting nutrient. Average yield increases attributable to N are 1.2 t/ha in the wet season and 1.4 t/ha in the dry season. In sites where several crops have already been grown, P is beginning to influence yield (Fig. 37).

The 1986 INSFFER training course drew 16 participants from 8 countries. Training includes theory, practice, and field trips on aspects of soil fertility and fertilizer management. After the 1986 monitoring tour of major rice-growing areas of China, the 20 participants planned 1987 network activities.



37. Response of irrigated rice to N, P, and K. Averages of 62 dry season and 77 wet season trials. International long-term fertility trial, 1976-85.

Asian Rice Farming Systems Network

Through ARFSN, IRRI and national programs jointly develop technology for nonrice crops and for production systems involving nonrice crops and livestock in the different rice environments. A working group of program leaders from each collaborating country and IRRI scientists meets once a year to review programs, discuss major issues, and plan collaboration.

Current collaborative research includes cropping pattern testing, testing upland crop varieties before and after rice, long-term cropping pattern and fertilizer studies, crop-livestock research, green manuring, and the role of women in rice farming.

Cropping pattern testing is done at 45 sites representing irrigated, rainfed lowland, upland, and partially irrigated rice areas in 12 countries: Philippines, China, Nepal, Pakistan, Indonesia, Thailand, Bangladesh, Madagascar, Sri Lanka, Taiwan, Malaysia, and Burma. Several cropping patterns at each site have been identified as biologically and economically better than existing farmers' cropping patterns.

Eight countries are involved in long-term cropping pattern and fertilizer studies: China, India, Bangladesh, Nepal, Thailand, Indonesia, Philippines, and Taiwan. The main thrust is to look at crop performance and effects on the soil for 3 years or longer. Crop-livestock research is conducted in collaboration with the Philippines, Thailand, Indonesia, Nepal, and China.

The most promising lines from our collaborations on varietal improvement are multiplied in IRRI and distributed to countries collaborating in testing upland crops before and after rice (Philippines, Indonesia, Thailand, Sri Lanka, Nepal, Burma, China, Madagascar, Pakistan, Vietnam, and Bangladesh). The varieties come from national agricultural research systems and other international agricultural research centers, including IITA, AVRDC, ICRISAT, and CIMMYT. ARFSN distributed 183 trials of different upland crops before rice and 204 trials after rice in the 1985-86 crop year. The crops are maize, sorghum, soybean, cowpea, peanut, pigeonpea, and mungbean. Collaborators identified several varieties as better than the two local varieties included in each trial.

Sesbania rostrata, a stem nodulating green manure, can provide a high amount of N to the next rice crop. In 1986, Thailand, Indonesia, Philippines, Sri Lanka, and Bangladesh began cooperative research on the biomass production of five *Sesbania* species in N substitution experiments.

Crop-livestock systems research within ARFSN is in collaboration with national programs and relevant research institutions (IRRI is not mandated to perform livestock research). Activities include on-farm crop-livestock trials in four key sites in Asia (Philippines, Indonesia, Thailand, Nepal) as well as with the Philippine Institute of Animal Science. The research is intended to generate technology appropriate for smallholder rice-based farming systems.

Women in rice farming

In 1986, we initiated collaboration through ARFSN on women in rice farming in the Philippines, Indonesia, Thailand, Bangladesh, and India. The major thrust is to incorporate concerns about women's employment and income into farming and cropping systems research methodologies. Sites involved are crop-livestock sites in Batumarta, Indonesia (upland rice); Pumdi Bhumdi, Nepal (rainfed lowland); Ban Phai (rainfed lowland) and Chiang Mai, Thailand (rainfed and irrigated lowland); Santa Barbara, Philippines, and several cropping systems sites in

Bangladesh. India will focus on the impact of improved technologies on women in rice-based farming systems and the problems and alternatives for women that are emerging. That research will involve 26 research institutions.

GLOBAL RESEARCH AND TRAINING SERVICES

IRRI's historical programs have a contemporary dynamism. Not only are the services growing in size, they are expanding their capabilities to provide the resources needed by the range of research programs, scientific focuses, and collaborations.

International Rice Germplasm Center (IRGC)

Although IRGC did not do primary field collecting during 1986, the collection continued to grow, as collectors from 28 countries deposited 4,159 samples. Overall holdings now total slightly more than 83,000 accessions.

Holdings alone do not adequately reflect the dynamic cooperation generated by the rice germplasm collection. This year, 39,130 seed samples were provided IRRI staff and trainees, 9,900 seed samples were sent researchers in national rice research programs and biotechnology research institutions. In addition, duplicate sets of their earlier deposits were returned to the large rice research stations at Patna and Maruteru, India, as their capacities for germplasm storage expanded. Other accessions of interest in those localities were added.

A major focus in 1986 was on training technicians for national programs. In the 12-month Genetic Resources Conservation and Management training course, 12 scientists from 8 Asian countries and 2 African countries came to IRRI for intensive training in the scientific principles and practical skills of genetic conservation (Fig. 38).

At IRRI, they planted seeds they had collected in their home countries and went through the entire germplasm

38. During the Genetic Resources Conservation and Management training course, the 12 scientists from 10 countries planted seeds collected in their home countries and characterized them for seed storage records.

preservation process — from registration, multiplication, characterization, and data entry to seed storage, maintenance, and regeneration.

The trainees earned the diploma Associate of IRRI, the first diploma of this kind awarded. The course was offered in association with the University of the Philippines at Los Baños and the Italian Government.

Seven technicians and four engineers from China also received practical training on genebank operations and maintenance of physical facilities. The China National Crop Genetic Resources Storage Center in Beijing, inaugurated in October, has long-term storage capacity for 400,000 accessions of many crops.

To help those Philippine rice farmers who would like to cultivate traditional lowland varieties not grown in recent years, 20 varieties with major appeal because of their eating quality were rejuvenated for further seed increase. Another 687 traditional varieties have been planted for seed increase. The seed will be transferred to Philippine agencies for further increase and distribution to interested farmers.

Germplasm improvement

IRRI continues its close collaboration with national rice varietal improvement programs. Since the mid-1960s, we have supplied seeds of parents, early generation segregating populations, and fixed breeding lines requested by national program scientists. These materials are evaluated in-country, some are released as varieties for farmer cultivation, others are used as parents in crossing programs.

In 1986, we supplied 40,798 seed samples of IRRI breeding lines to national programs, in addition to the

42,673 seed samples distributed through the IRTP nurseries.

This collaboration has resulted in the release by national programs of 155 IRRI breeding lines as varieties. Those varieties are now being grown on vast areas of countries of Asia, Africa, and Latin America (Fig. 39).

Shuttle breeding

Rice is grown under diverse environments and subjected to many different stresses: drought, excess water, cold temperatures, and soil problems. To speed our progress in developing improved varieties for the many stress situations, early generation segregating materials must be exposed to the actual stress. Most of those stresses do not occur at IRRI headquarters in Los Baños.

For more rapid progress, we have developed shuttle breeding in collaboration with rice researchers in localities where the adverse stresses actually occur (Fig. 40).

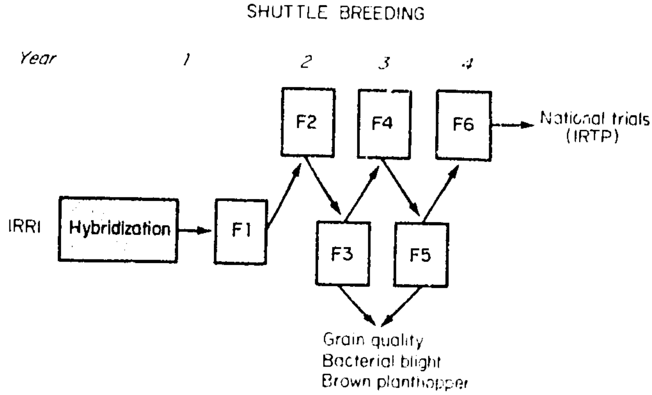
Parents that can contribute the desired resistance or tolerance to a cross (usually an improved variety or breeding line from IRRI and a locally adapted variety of the collaborating country) are selected jointly by IRRI and national scientists. Crosses are made and the F_1 progenies grown at IRRI. The F_2 populations are grown in the target environment, where they are exposed to the appropriate stresses.

39. Nine IR breeding lines were named and released as varieties by six national programs in 1986.

Country[a]	Name	Breeding line
Brazil	Empasc 104	IR841-167-1-2
Sierra Leone (Liberia)	IR4422	IR4422-198-3-6-1
Nigeria (Philippines, Indonesia, Brazil, Ivory Coast, Cameroons)	IR46	IR2058-78-1-2-3
Indonesia	Tajun	IR4744-295-2-3
Indonesia (Philippines)	IR48	IR4570-83-3-3
Vietnam	NN5B	
India	Himalaya 741	IR3941-45-P1p-28
India	Pant Dhan 6	IR19728-9-3-2
India	PR109	IR28224-66-2

[a]Countries named in parentheses had released the variety earlier.

40. Shuttling between two locations for growing alternate generations of rice breeding lines facilitates selection for stress tolerance in the target environment as well as for disease and insect resistance and grain quality.



Seeds of locally adapted plants selected from the F_2 population are returned to IRRI for evaluating F_3 progeny resistance to diseases and insects and for grain quality.

Selected F_4 progeny may again be planted in the target environment and the F_5 at IRRI.

We have shuttle breeding projects for developing breeding materials with cold tolerance and with adaptability to rainfed lowland, tidal wetland, and deep water conditions.

Screening for adverse soil tolerance

During 1976-85, 200,000 varieties and lines from the world collection and IRRI's breeding program were screened for soil stresses; 15% were identified as tolerant of salinity, alkalinity, acid sulfate soil conditions, and peat soils. Some of these tolerant lines, including multiple stress-tolerant IR36, IR42, IR54, and IR9764-45-2, are being used in national breeding programs.

Sources of insect resistance

The inherent plasticity and adaptability of rice insect pests dictate continual screening and breeding for resistance. Recently, resistance to the brown planthopper in IR36 and IR42 was found to be eroding in some locations. We evaluated more germplasm collections and breeding lines for resistance to nine major insect pests and identified a number of resistance sources (Fig. 41).

Drought resistance

Drought and blast, major constraints to profitable and stable rice production in most dryland areas of the world, are location specific. To help national programs accelerate the development of improved breeding material adapted to local conditions, we are making crosses to meet national rice scientists' breeding objectives. The national scientists define the desired traits, IRRI scientists make the crosses. During 1986, 47 crosses to recombine early maturity, drought resistance, and gall midge resistance were made for India. Another 31 crosses were made for Senegal, 24 for Zanzibar, 13 for Mexico, and 3 for Thailand. Zanzibar, Mexico, and Thailand sent local varieties to IRRI to use as parent material in the crosses. Earlier in the year, 15 backcrosses were made for Thailand and 69 single crosses for Mexico.

Professional advancement programs

We endeavor to strengthen the scientific manpower resources of national organizations through our training and professional advancement programs. IRRI's training programs are designed for research workers from field technicians to scientists and research managers.

The Visiting Scientist and Postdoctoral Scientists Program brings senior scientists to IRRI for work on research problems of mutual interest to their home

41. Germplasm and breeding lines screened for resistance to insect pests. IRRI, 1986.

Insect	Germplasm		Lines	
	Tested (no.)	Resistant (%)	Tested (no.)	Resistant (%)
Brown planthopper biotype 1	3,351	<3.4	53,050	77.5
Brown planthopper biotype 2	0	0	37,862	57.6
Brown planthopper biotype 3	0	0	27,666	70.0
Green leafhopper	3,457	1.1	75,580	46.4
Whitebacked planthopper	3,881	2.2	4,240	6.2
Striped stem borer	0	0	73	4.1
Yellow stem borer	2,112	9.2	1,835	29.2
Cnaphalocrocis medinalis	5,150	5.2	6,701	21.5
S. biformis	392	29.2	0	—
Whorl maggot	1,241	0	128	0
Caseworm	1,590	0.31	128	0

countries and IRRI, using the modern research facilities of the Institute.

Through the degree program, middle-level research scientists study toward masteral and doctoral degrees. Coupling the academic programs of leading agricultural universities and the research facilities and expertise of the Institute, the degree training program offers a wide spectrum of specializations beneficial in the agricultural development of many countries, particularly where facilities for graduate education are limited.

Courses in the rice science and support disciplines also are offered to support the research activities of IRRI's international research network. Fourteen such courses were offered in 1986 to train scientists in the concept skills and principles of production practices, water and pest management, farming systems, and genetic conservation, in addition to new courses in statistical procedures and computer applications and editing and publication.

During the year, 568 scientists from 42 countries participated in our various training programs: 254 in research-oriented programs designed to upgrade the skills of middle-level and senior research scientists, 314 in regular and special training courses conducted at IRRI headquarters and abroad. Of this group, 342 completed their training.

Graduate study collaboration

To support its degree training programs, the Institute has entered into graduate program collaborations with about 30 agricultural universities all over the world. Seven new programs were formalized in 1986.

University	Country
Zhejiang Agricultural University	China
Chonnam National University	Republic of Korea
Thammasat University	Thailand
Sokoine University of Agriculture	Tanzania
Universidad Sukonoma de Nueva Leon	Mexico
Universidade de São Paulo	Brazil
Louisiana State University	United States
Narendra Deva University	India

The agreement with Universiti Pertanian Malaysia, originally established in 1981, was renewed for another 5 years.

This year, a graduate program on farming systems was initiated by Bangladesh Rice Research Institute (BRRI), IRRI, and Bangladesh Agricultural University (BAU). Scholars complete their course requirements at BAU and conduct thesis research at BRRI or IRRI, or both.

As new collaborative projects evolve, the need for training on standard research methodology becomes apparent. Two scientists were trained on monitoring and diagnosing rice virus diseases and four on monitoring the susceptibility of rice insect pests to insecticides.

A new course in Training and Technology Transfer teaches the concepts and skills used in designing, implementing, and evaluating training programs. Topics include human resource development, curriculum development, managing training programs, educational psychology, media adaptation and development, training methodologies, and testing and evaluation. Like all IRRI courses, it is practical and applied, with at least 50% involving laboratory exercises and projects.

Through cooperative projects, we are offering courses in-country as well as at the Institute. Teams from national systems take the Training and Technology Transfer course so that they may tailor IRRI courses to meet their specific needs. In 1986, teams from Bhutan, Burma, Indonesia, Philippines, and Sri Lanka developed courses in farming systems, rice production, post harvest technology, and training of trainers.

A special course on cowpea and soybean was conducted in Thailand under the auspices of IRRI, IITA, UNDP, Khon Kaen University, and the Department of Agriculture of Thailand.

Cooperative publishing

To enhance current research awareness among national scientists, IRRI publishes the *International Rice Research Newsletter* (IRRN). Six issues per year plus a subject index go to 16,000 rice workers in 152 countries. The IRRN averaged 29 pages per issue in 1980, by 1986, it had increased to 42 pages. National program scientists submit some 100 research briefs a month.

A new journal, *Rice abstracts,* was initiated in 1986 in cooperation with CAB International. The Asian Development Bank supports 1,000 free subscriptions to key Third World libraries.

IRRI's copublication program — joint ventures with national programs to publish translations of IRRI books — continues to grow. At least 91 non-English editions of 23 IRRI books have been copublished in 36 languages in 19 countries. The most popular are extension-level books designed to facilitate easy and inexpensive copublication. *A farmer's primer on growing rice* has been published in 30 languages; *Field problems of tropical rice* has been published in 20 languages.

Two new farmer's primers — on growing soybean and cowpea on riceland — are being published and distributed jointly with IITA. Another primer on growing upland rice will be published jointly with IRAT.

In 1986, IRRI studied the effectiveness of the Pilipino and Hiligaynon editions of *A farmer's primer on growing rice* among 84 small-scale farmers in Cavite and Negros, Philippines. Only 4% of the farmers had substantial knowledge of rice-growing practices before reading the book. After reading, 56% obtained high scores. That evaluation of the primer's design and content is being used to tailor three new primers and to revise the original.

Helpful insects, spiders, and pathogens — friends of the farmer, released in late 1986, has 103 color photos and illustrations to help farmers identify and protect the predators, parasites, and pathogens that live in every ricefield and that can control most rice pests without insecticides. In format, it matches *Field problems of tropical rice.* Translations into Burmese, Pilipino, and Ilokano began from advance copies of the pages. Indonesia has ordered 20,000 copies in Bahasa Indonesia to support its IPM program.

In 1986 IRRI distributed almost 200,000 books, in English and in Third World languages, plus 121,842 copies of our periodicals. More than 136 Basic Set — all IRRI materials in print — have been distributed to help national libraries rapidly and inexpensively establish their own basic collections of rice literature.

Much of the results of research carried out in the developing countries never reach the people who can benefit from them — other scientists, extension workers, and the farmers themselves — for lack of people skilled in the techniques of communication. IRRI, with support from the IDRC of Canada, has developed an intensive 14-week Editing and Publication Training Course which covers the essentials of editing and publishing with a mixture of analysis and hands-on practice. Three such courses have been given to trainees from national and regional organizations in 15 countries.

The program is designed so that teaching material modules can be adapted, translated into local languages, and taught in-country by national agencies. A 3-week course has been offered at the Central Research Institute for Food Crops (CRIFC) in Bogor, Indonesia. The faculty of that course included one graduate of the IRRI course. Sixteen trainees from agricultural research institutes across Indonesia took part. Two more courses are planned.

Computer Center

Increasing use of computers in national programs, international centers, and advanced research institutes has increased demands for counseling and technical support. We helped the BRRI set up its own computer center this year and are developing computer-based training courses.

COLLABORATION WITH NATIONAL PROGRAMS

ur memoranda of agreement with many countries of the world not only help us identify the research that IRRI can provide as the building blocks for national agricultural research planning and implementation; they also enable national programs to cooperate regionally and globally.

IRRI's relationships with national programs pass through different phases, with technical assistance shifting to cooperative programs and collaborative research as national resources grow. Currently, IRRI has cooperative agreements which taken together account for more than 85% of the world's ricelands and rice production.

A common model of cooperation with a national agricultural research system begins with IRRI being invited to participate in a country program. Early priorities usually involve human resource development and participation in research networks.

As national capability increases, participation in networks becomes more specialized and contributory. Scientific collaboration on specific research problems may grow to become the major ingredient of a country's program. At the most advanced stage, a national agricultural research system may assume regional or global responsibilities based on its comparative agro-ecological and scientific advantages.

Our cooperative agreements with some countries are long-standing — almost since IRRI's inception. Other agreements are quite recent. All memoranda of agreement are reviewed periodically and refined to reflect achievements and to incorporate newly identified needs, capabilities, and priorities.

We have space to expand on only a few of the IRRI-country collaborations that illustrate the range.

COLLABORATIVE AGREEMENTS

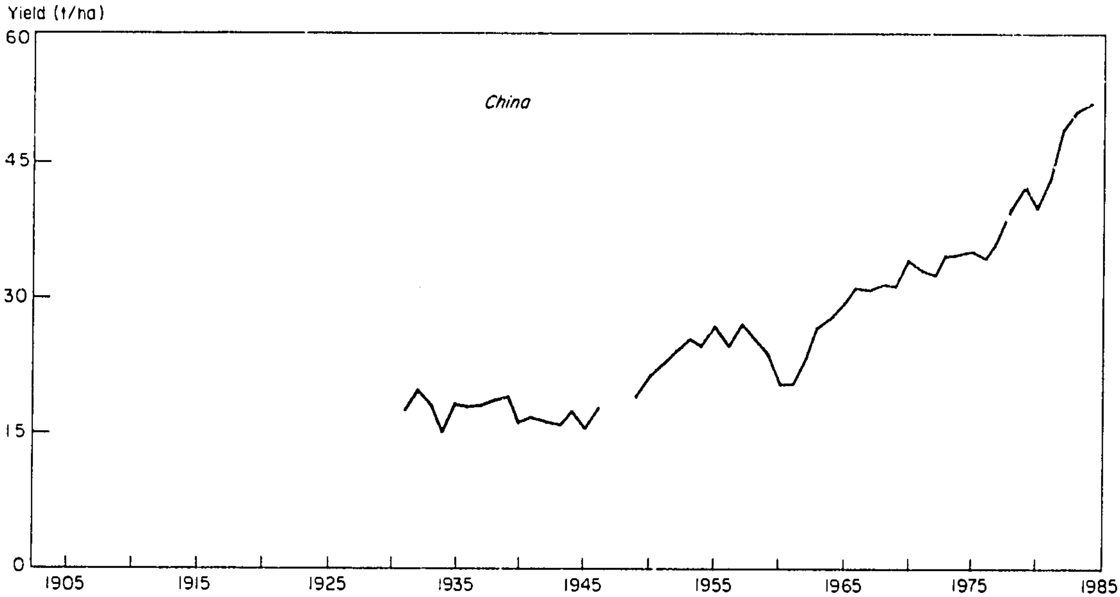
Normally, the initiation of an IRRI-national research system collaborative program involves these steps:

- *The country concerned initiates the request for cooperation, based on a decision by its government to increase the productivity of its rice-growing areas.*
- *If, in IRRI's view, opportunities exist for significant increases in rice productivity utilizing improved technologies and methodologies, IRRI scientists and national program scientists together explore these opportunities.*
- *Where substantial assistance is needed, which could include positioning expatriate scientists in the collaborating country, IRRI and the concerned national program seek special project funding from suitable donors.*
- *Once a program is agreed upon and research is underway, its progress is periodically reviewed and its focus adapted to encompass achievements.*

China

China is the world's largest producer and consumer of rice, with a long history of rice cultivation and rice science, technology, and production improvement.

Chinese scientists from the China Academy of Agricultural Sciences (CAAS), China National Rice Research Institute (CNRRI), and provincial agricultural academies have participated for more than 6 years in IRTP, INSFFER, and ARFSN. Nearly 600 Chinese scientists and administrators have been trained at IRRI, as scholars and in training courses. Scientists from many countries have participated in jointly sponsored training courses, symposiums, conferences, and workshops in China. Germplasm exchange continues on a large scale.



Historical rice yield trends

The development of hybrid rice was a great breakthrough in rice breeding and a technical innovation in rice production. IRRI and China actively collaborate on developing elite restorer lines and cytoplasmic male sterile lines with early maturity, high yield, good eating quality, and multiple resistances to diseases and insects. We jointly conduct training courses and have published a training manual on hybrid rice technology. The cosponsored International Symposium on Hybrid Rice was held at the Hunan Hybrid Rice Research Center 6-10 Oct 1986.

When the Chinese Government decided to set up a national rice research institute, IRRI participated from the beginning in its conceptualization and developm :nt. Five IRRI scientists were consulted on designing CNRRI buildings and rice breeding, cereal chemistry, grain quality analysis, and farming systems research. At the same time, 17 CNRRI scientists came to IRRI to study recent advances in science and research management. IRRI scientists also have advised on the purchase of research equipment.

CNRRI's construction is being implemented at two sites — in Hangzhou and at the experiment station in Fuyang County. Three of the research facilities under construction now at the experiment station will be inaugurated during the International Rice Research Conference in September 1987.

A shuttle breeding project with CNRRI started in 1983 to collaboratively develop cold tolerant varieties with superior grain quality and multiple disease and insect resistances. Seeds of nine short-duration Chinese varieties were crossed with four elite IRRI breeding lines. The F_1 seeds of 36 cross combinations were planted at IRRI in Dec 1983.

The F_2 seeds were planted at CNRRI farm in late Apr 1984 and 1,653 short-duration plants with blast resistance and good grain appearance were selected in August. The F_3 was planted at IRRI in November and field inoculated with bacterial blight and evaluated for resistance to brown planthopper.

From this F_3, 2,592 selections were made in February-March 1985. The F_4 was planted in April, half at Hangzhou and half at IRRI. That screening yielded 1,915 selections, with the F_5 planted in November 1985 at both Hangzhou and IRRI. Uniform rows were bulk harvested in Feb 1986 and an additional 2,128 individual plant selections were made. The F_6 was planted in China in early April, and observational yield trials were planted at both IRRI and CNRRI.

Several promising lines have been selected for replicated field trials in 1987.

Lu Ze Tung, rice breeder, CNRRI, and G. S. Khush, examining shuttle breeding materials at Hangzhou, China.

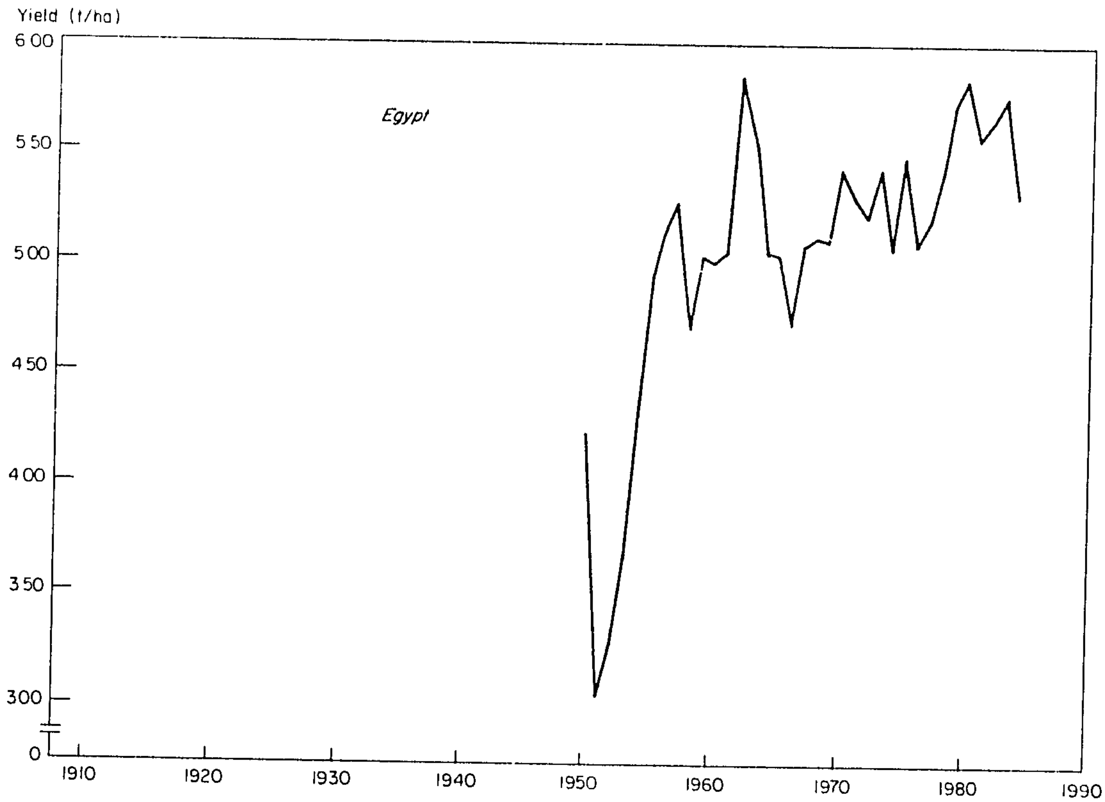
The National Azolla Research Center at Fuzhou is gradually developing the capacity for international research and training in the use of azolla as a N source for rice. Azolla has been cultivated in China for generations.

The collaborative program of IRRI and CAAS is guided by the Memorandum of Understanding agreed upon during the joint annual planning session, when administrators and scientists of both institutions review progress and formulate the program of work for the next year. The next planning meeting will be in Beijing in July 1987.

Egypt

The collaboration has generated important research directions. With its scarcity of arable land, Egypt's agricultural research program focuses on improving productivity and cropping intensity.

Historical rice yield trends



Breeding to combine high resistance, high yield potential, resistance to lodging, blast resistance, and short duration in new varieties is a major part of the program. Several lines combining desired agronomic and quality features with diverse sources of disease resistance have been identified.

The most encouraging aspect of these breeding efforts is that a continuous chain of blast resistant lines is developing. These lines are primarily japonicas, but because IR indicas have short duration and good resistance to blast, they are becoming more common.

Pathological research also intensified, with emphasis on identifying strong and diverse sources of resistance, screening breeding lines, identifying blast races, and measuring the weather parameters that favor disease development.

The Rice Research Center at Sakha is unique in the Middle East/North Africa area. Rice is being researched as both a food crop and a problem soils reclamation crop.

IRRI also has agreements with the University of Cairo and the Academy of Scientific Research for collaborative graduate study programs.

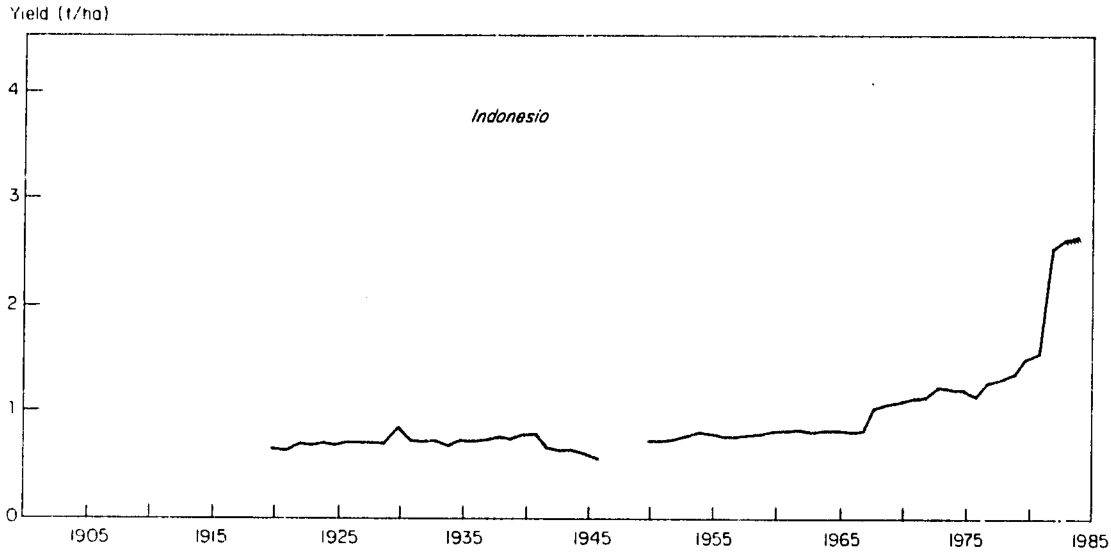
Indonesia

IRRI-Indonesia cooperative research has evolved into true collaboration. Under the memorandum of understanding, priority is given to genetic evaluation and utilization and resource exchange, upland rice cultivation, rice-based farming systems, water management, farm machinery development, increasing the technology base through training, graduate studies, nondegree attachments to IRRI, conferences and workshops, and exchange of technical information and publications.

Indonesia hosted the 1985 Upland Rice Research Conference, which has led to further collaboration in work on blast disease and management of acid upland soils.

The five major rice environments are all found in Indonesia.

In irrigated rice, productivity is very high but diseases and insects are a constant threat to yield stability. Exchanging improved materials with multiple resistance



Historical rice yield trends

continues; all elite IRRI breeding lines are being evaluated in Indonesia

In rainfed lowland rice, three very short-duration breeding lines from IRRI performed well on Lambok Island and are being considered for varietal release. Several more improved breeding lines with even shorter growth duration will be evaluated.

In upland rice, exchange of adapted germplasm will be expanded with improved breeding lines for acid upland. Indonesian upland rice varieties from the Bogor germplasm collection will be evaluated in the Philippines for adaptation to low pH, upland soils, and allied stresses to identify parents for upland rice breeding programs.

In deep water rice, Indonesian scientists identified three promising breeding lines introduced through IRTP nurseries that are adapted to deep water areas of South Kalimantan. Even better materials have been generated from crosses with these selections.

In tidal wetlands, IRRI has greatly expanded rice improvement efforts for developing improved germplasm adapted to submergence, salinity, and peat with acid sulfate conditions in a multiple stress environment. F_2 seeds of a number of crosses will be planted at Unit Tatas Experiment

DEEP WATER RICE VARIETIES RELEASED IN SOUTH KALIMANTAN

Tapus (*IR36/Leb Mue Nahng 111*) *was developed collaboratively by IRRI and the Thailand Rice Research Institute via rapid generation advance. The tall (154 cm in shallow water), leafy, floating rice is photoperiod sensitive with good ability to elongate in 2 m water. Tapus is resistant to bacterial blight (race 1), moderately resistant to blast, resistant to brown planthopper biotypes 1, 2, and 3, and moderately susceptible to green leafhopper. Grains are long slender and slightly chalky with 26.3% amylose content and hard gel consistency (33.5).*

Nagara (*IR2061-465-1-5-5/Leb Mue Nahng 111*) *was developed in Thailand. It is short statured (117 cm in shallow water), has little photoperiod sensitivity, flowers in 102 days, and has excellent elongating ability. Nagara is resistant to bacterial blight (race 1) and to brown planthopper biotypes 1 and 3, and moderately resistant to green leafhopper. It has slender, chalky grain, 25% amylose content, and hard gel consistency (32.5).*

Alabio (*Leb Mue Nahng 111/IR8*) *was developed in Thailand. It is 118-135 cm tall in shallow water, photoperiod sensitive, with moderately good elongation (164 cm). It is moderately resistant to bacterial blight and blast. Grains are slender and translucent.*

Station in South Kalimantan. The F_3 of selected plants with appropriate growth duration and stress tolerance will be grown at IRRI and evaluated for grain quality and disease and insect resistance. The shuttle of the F_3 back to Unit Tatas should lead more quickly to improved materials for these adverse conditions.

In hybrid rice, new CMS lines and F_1 hybrids from IRRI will be evaluated to identify more promising materials. Chinese CMS lines are adapted but susceptible to diseases and insects; IRRI CMS lines are resistant but have poor seed set in seed production plots. IRRI will train Indonesian staff on hybrid seed production.

In integrated pest management, the Agency for Agricultural Research and Development in collaboration with IRRI is intensifying research on more effective control of brown planthopper outbreaks and tungro virus disease.

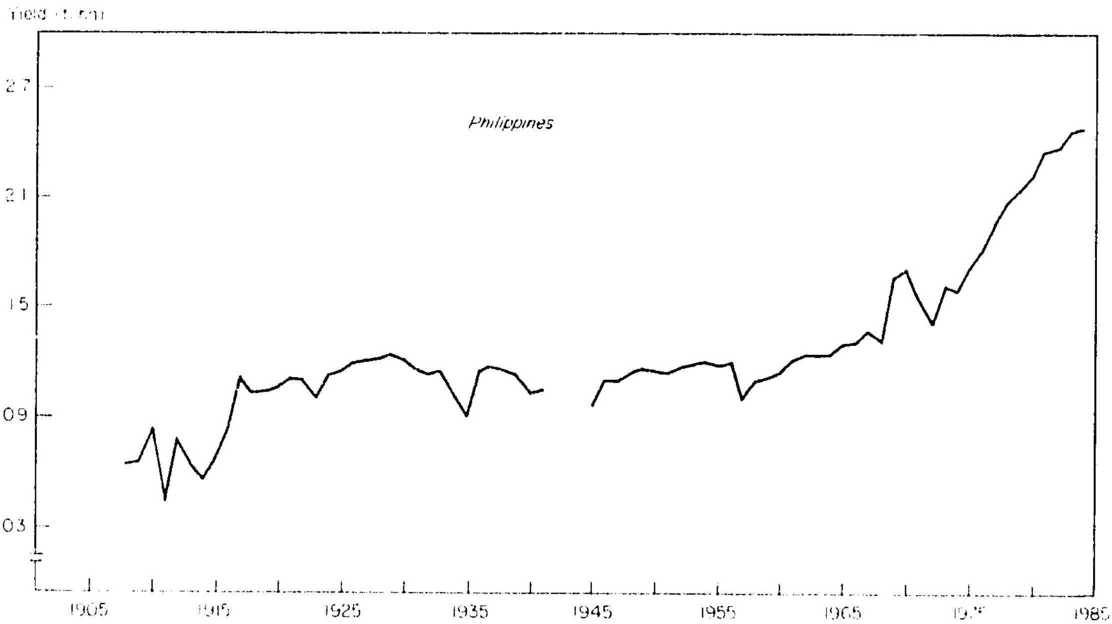
The President of Indonesia has announced a far-reaching policy of IPM that recognizes the adverse effects of nonselective use of chemicals.

A technical cooperation with the Directorate General of Food Crop Agriculture provided special training and technical advisers on constructing the IRRI warehouse dryer, including installing vortex wind machines on traditional storage structures in the villages.

Philippines

Our cooperation and collaboration with the Philippines recognizes the role of the Philippine Government in the establishment of IRRI and its continuing support, along with the contributions of our Filipino staff and our long history of partnership with Philippine agricultural institutions, notably the Ministry of Agriculture and Food (MAF) and UPLB.

Further strengthening of the collaboration between IRRI and Philippine scientists is anticipated with the establishment of the Philippine Rice Research Institute (PhilRice) in 1986. PhilRice is mandated to develop a strong national rice research program to sustain and further improve the gains already made in rice production. The Board of Trustees of PhilRice has expressed the need for close collaboration with IRRI in achieving its goals of national rice self-sufficiency and increased income and



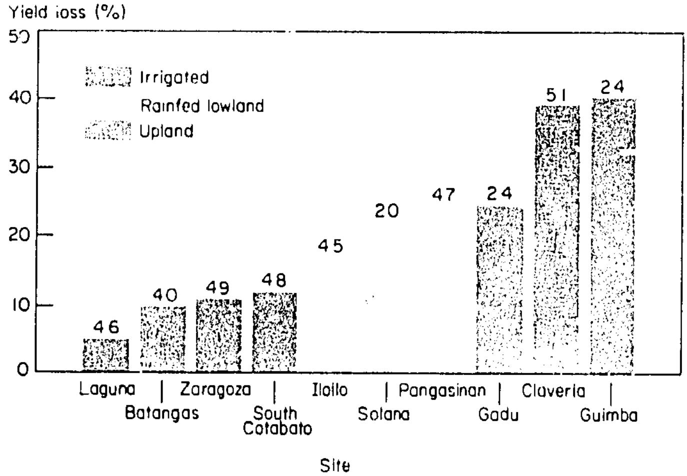
Historical rice yield trends

employment opportunities for Filipino rice farmers and their families.

An important mechanism for exchanging information and developing collaborative work plans with Philippine rice workers is the biannual Technology Transfer Workshops. The 8th MAF-IRRI Technology Transfer Workshop at IRRI 13-14 June 1986 focused on technologies that can reduce production costs without lowering yields. Collaboration in integrated nutrient management and integrated pest control were initiated.

The 9th MAF-IRRI Technology Transfer Workshop in November was held in Bohol, an upland farming province in the Central Visayas. At this workshop, 117 participants from IRRI and Philippine agencies reviewed the development of upland rice farming systems. Upland rice farmers become commercially oriented when inputs, credit, and produce markets are available. In the more remote slash and burn areas, opportunities for selling extra produce are few. Workshop participants agreed that such local variations in upland rice farming systems should be considered in developing programs for their improvement.

42. Yield losses caused by insect pests in irrigated, rainfed lowland, and upland rice areas in the Philippines. Losses were calculated as the difference between insecticide protected plots and unprotected plots in farmers fields. Numbers are the average yields (in t/ha) from protected plots.



43. The upland-acid soils MAF-IRRI cropping systems research site in Mindanao is illustrative of how population pressures are converting tropical forest ecosystems to cropland, and the implications of that change to farmer fertility management practices.

Early in 1986, we counted more than 75 projects underway in collaboration with scientists in at least 40 Filipino institutions. Reports of a few of the accomplishments of those collaborations follow.

Yield losses to insects. Ten years of farmers' field trials in collaboration with the Philippine Ministry of Agriculture show high variability in yield losses — 5-40% in irrigated lowlands, 10-39% in rainfed upland environments. Locations with high lowland rice yields had the lowest losses; locations with the highest upland rice yields had the highest losses. Rainfed lowland fields lost 16-24% (Fig. 42).

In lowland sites, losses correlated weakly with insect numbers, indicating that other site-related factors affecting yield influence a crop's ability to tolerate insect damage.

Response of upland rice to fluazifop-butyl. In our collaboration with the UPLB Weed Science section, only a few postemergence herbicides showed promise for controlling weeds in upland rice. Fluazifop-butyl, a grass killer recommended for broadleaf crops, may be used safely in upland rice; at the recommended application rates and timing, it controls such weeds as *Rottboellia cochinchinensis* (Lour.) Clayton.

Soil fertility management in Claveria. At the upland-acid soils MAF-IRRI cropping systems site in Mindanao, knowledge about farmer fertility management practices and perceptions is applied to designing and testing cropping patterns. We surveyed farmers on their perceptions about soils and soil erosion, fertilizers, weeds, and fallows (Fig. 43). We also asked about migration and settlement, land resources and access, crops and cropping, and yield changes over time.

Throughout the uplands, as populations have increased agriculture has evolved from shifting cultivation, with fallow used for nutrient regeneration, to permanent cereal cropping (Fig. 44). Most Claveria farmers are smallholding tenants or owners who manage several crops. Traditional maize is the most important, followed by traditional rice and cassava. Better lands are allocated to maize, poorer soils to rice or cassava. Rice is a desirable crop, but its longer cropping season and its greater labor demand contribute to a preference for maize.

44. Claveria farmers say sustainable yields are a great concern, as maize and rice yields are declining because of poor soils, nutrient depletion, and erosion.

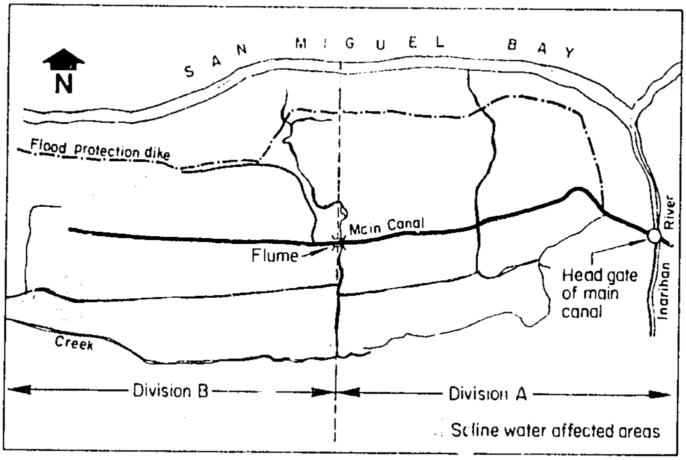
Sustainability is very much a Claveria farmer problem. Almost all of them attribute declining maize and rice yields to poor soils, nutrient depletion, and soil erosion.

Although knowledge of nutrient cycling methods, such as composting, mulching, green manuring, and incorporating crop residues, is limited and variable, it is increasing. A few farmers practice composting, and more now incorporate crop residues.

Water use efficiency and distribution. Water management research collaboration is with the Philippine National Irrigation Administration (NIA). We are studying the Inarihan River Irrigation System (IRIS) in Camarines Sur Province.

IRIS has a potential service area of about 1,100 farm families and about 1,400 ha; about 30-40% of the area is affected by saline water intrusion from the sea. Supplying sufficient good quality irrigation water to leach the salts is extremely important for rice production. The service area is divided into Division A, with 647 ha, and Division B, with 743 ha of ricelands (Fig. 45).

Our primary research objectives are to assess the potential for improving water use efficiency and water allocation-distribution equity, to develop a practical allocation-distribution system, to evaluate its impact on rice production and farmer income, and to analyze the effect of irrigation water on salt-affected land productivity.



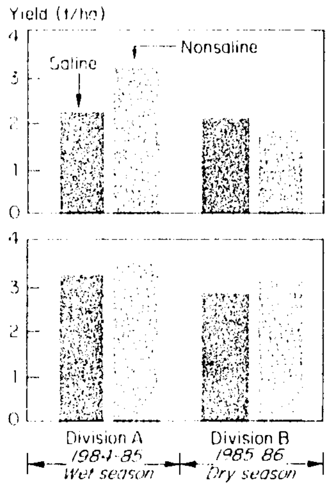
45. The Inarihan River Irrigation System in Camarines Sur, Philippines, has areas that are affected by saline water. This schematic shows the service area.

The area near the water source — about 47% of the service area — consumed 70-76% of the total irrigation supply. Those farmers used more N, P, and K fertilizer than farmers whose farms suffered water shortages, particularly during the dry seasons. Farms with nonsaline soils near the water source had the highest yields; farms with saline soils farther from the water source had the lowest (Fig. 46).

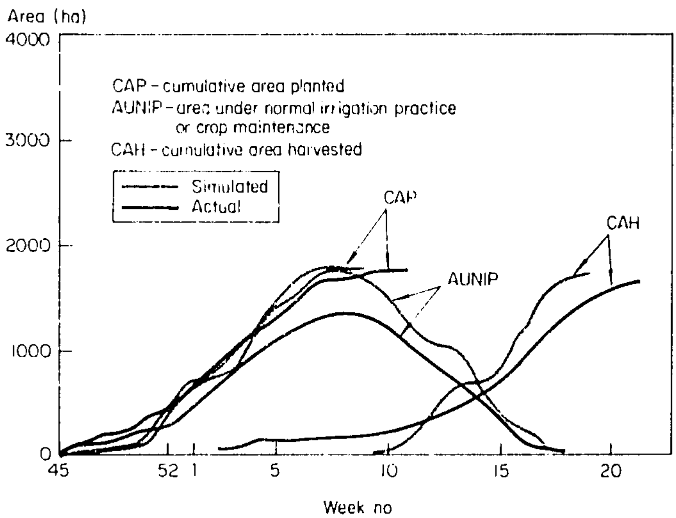
Simulation model for multipump irrigation systems. In collaboration with NIA, we developed a methodology to improve the operational efficiency of the Libmanan-Cabusao Pump Irrigation System (LCPIS). LCPIS has four electrically driven turbine pumps to service a rice production area of about 3,900 ha. We used data from the LCPIS study to develop a microcomputer-based simulation model (PUMPMOD) for analyzing system behavior under continually changing water demands (Fig. 47). The model accounts for such operational constraints as power supply rationing and canal capacity limitations, as well as socio-economic constraints in land preparation rate.

PUMPMOD is adaptable to other pump irrigation systems. It closely approximated actual hydrological and agronomic changes in response to a chosen system operational procedure.

Appropriate mechanization. IRRI has collaborated with the Philippine MAF to encourage local manufacture of



46. Average wet and dry season yields in saline and nonsaline soils irrigated by IRIS, 1984-86.



47. Actual and PUMPMOD-predicted changes in farming activities for Libmanan-Cabusad Pump Irrigation system, Philippines, dryseason 1985.

appropriate farm machines. Two irrigation pumps developed for small farmers received major attention. The tapak-tapak pump, adapted from a simple Bangladesh bamboo pump, can be manually operated to pump water from shallow wells. This pump was acceptable to small farmers in northwestern Luzon for irrigating vegetables, legumes, tobacco, and other crops grown after rice. The pump can be fabricated by small rural shops (Fig. 48).

The program also helped popularize the sipa pump, which is based on the principle of the axial-flow propeller pumps popularly used in Vietnam and Thailand. The sipa pump is adapted to Philippine conditions on the basis of feedback from farmers. In collaboration with small manufacturers, it is now manufactured by over 20 small metal-working shops.

A rotary conduction dryer that utilizes a rice hull gasifier as a heat source was also introduced. The gasifier, a

48. Demonstration of tapak-tapak pump in La Union, Philippines.

simplified version of Chinese design, was adapted by the University of California, Davis, and developed in the Philippines in collaboration with a commercial rice mill and a local manufacturer. In an hour, it can dry about 1 t of freshly harvested grain to 16-18% moisture, a level safe enough for temporary storage before sundrying to 14%. It is suitable for areas where rice is harvested during the wet season, when sundrying is difficult.

In areas where direct seeding is gaining popularity, farmers are showing high interest in the IRRI drum seeder. With this low-cost machine, pregerminated seed can be planted in rows which can be economically weeded with push type mechanical weeders, savings over costly herbicides.

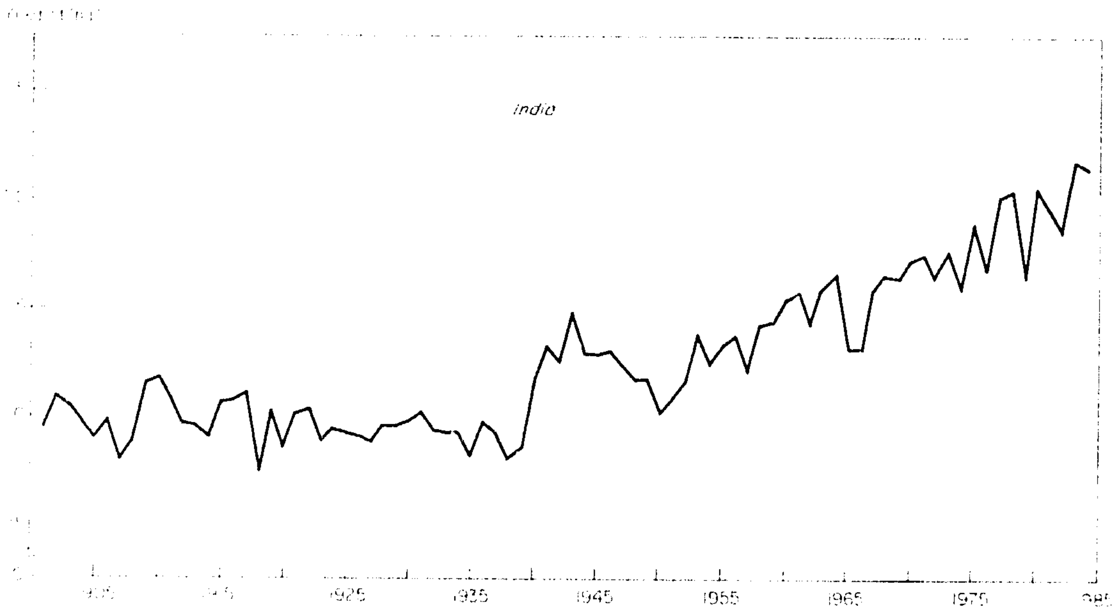
We cooperated with the Agricultural Mechanization Development Program (AMDP) of UPLB, MAF, and the provincial government of Mindoro to introduce this machine to farmers and manufacturers. A 2 week training program was organized for 10 manufacturers in Naujan, Oriental Mindoro, after many farmers expressed a desire to purchase the seeders during the series of demonstrations conducted by MAF and AMDP. Local production has started.

The warehouse dryer was introduced to a farmers' cooperative in Barangay Molicay, Ozamis City, for field testing.

India

The first memorandum of agreement between the Indian Council of Agricultural Research (ICAR) and IRRI was signed in 1974, although cooperation started some 10 years earlier. Scientific and technical cooperation focused first on collecting and exchanging rice germplasm, exchanging and evaluating breeding materials, studying diseases and insect biotypes, and conducting crop production research.

By 1986, collaborative efforts included rainfed rice research, hybrid rice research, botanicals for managing insect pests in rice-based cropping systems, the economics of water management, rice production constraints, and manufacture of IRRI-designed small farm machinery. The collaborations between IRRI scientists and Indian scientists in 22 agricultural universities, 50 central research institutes, and 90 All-India Coordinated Research projects in the country's different agroclimatic zones continue to evolve.



Historical rice yield trends

During 1986, 64 scientists from agricultural universities and national research organizations participated in training and professional advancement programs and workshops at IRRI. We also entered into a formal agreement with the Indian Agricultural Research Institute and Andhra Pradesh Agricultural University for graduate training of agricultural scientists.

A special rice production program was designed for senior extension officers of several states. Participants in training and technology transfer short courses have helped improve the professional capabilities of their home institutions. Now, the Indian national system is developing the capability to offer these short courses in the agro-ecological regions with rice cropping and rice-based farming systems. One of the in-country programs will be an editing and publications training course to strengthen national communication capabilities in disseminating information and communicating new technology in rice production.

Special collaborative research and training programs have been organized in integrated pest management for deep water rice farming systems and in developing improved varieties for ecologically handicapped areas.

Recently, the International Fund for Agricultural Development approved funding for an IRRI-ICAR collaborative research program for the development of rainfed rice production in eastern India. Resolving the complex problems which cause the very low rice yields in that area is a major challenge to rice scientists.

Major components of the project are rice environmental analysis, varietal improvement, rainfed rice crop management, development of more productive rainfed cropping patterns, and postharvest technology. Research and training are integrated throughout.

In 1987, pests and diseases will be surveyed in an integrated pest management in deep water rice supported by the Asian Development Bank, farmer agronomic practices will be documented, and the deep water rice areas in five states in eastern India mapped.

A 1-week training course in August coordinated a standard methodology for a network linking Assam Agricultural University, Rajendra Agricultural University in Bihar, Orissa University of Agriculture and Technology, Narendra Deva University of Agriculture and Technology in Uttar Pradesh, and the West Bengal Department of Agriculture. The project is also collaborating with the Ramakrishna Missions at Narendrapur and Nimpith. In 1987, this Indian network will be linked with IRRI cooperators in other Asian countries where deep water rice is researched.

Bangladesh

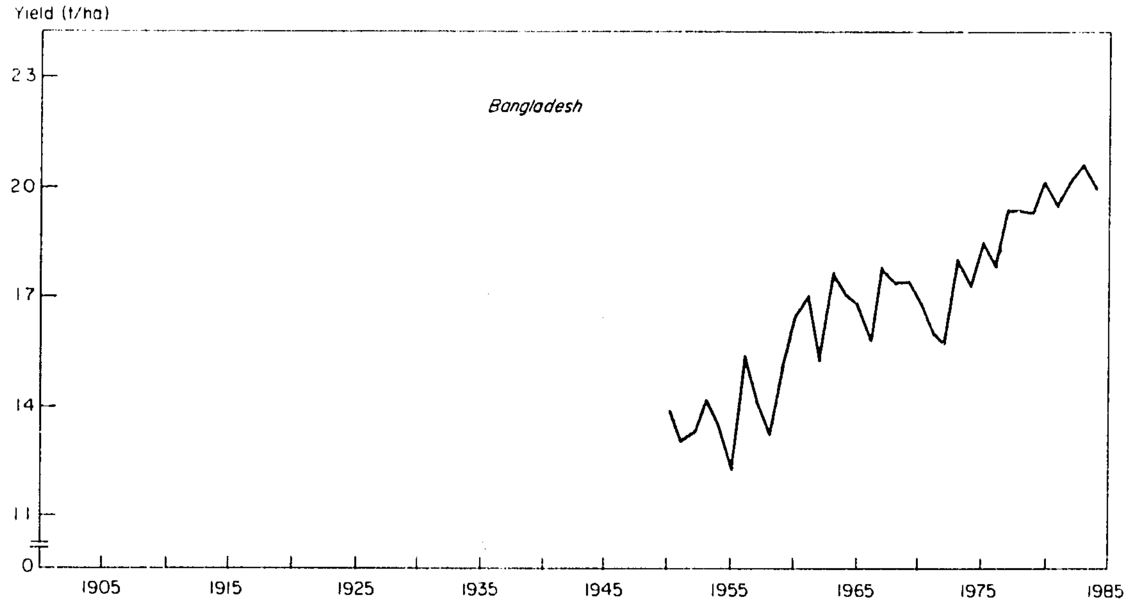
When the BRRI was established in 1973, IRRI was represented on its Board of Governors. The current 6-year memorandum of understanding was ratified December 1985, with the goals of increased productivity, expanded attention to rice-based farming systems, and increased local manufacture of small-scale agricultural machinery. Two IRRI outreach scientists are an integral part of BRRI's program.

One component of our Bangladesh collaboration is water management research with the BRRI and the Bangladesh Water Development Board.

The aim is to increase the effectiveness of irrigation water use, crop production, and farmer income in two types

DIESEL POWERED
PT5 TILLER

Most Indian farmers prefer diesel engines because of the lower cost of diesel fuel, even though the initial investment is much higher than for a gasoline engine. But diesel engine weight and vibration restrict their use on lightweight mobile farm machines. The CIAE-IRRI Industrial Extension Project helped a manufacturer in Coimbatore adapt the IRRI PT5 power tiller with 1.0 m reaper for powering with a locally manufactured 6 HP air-cooled Lombardini diesel engine. This engine weighs only 35 kg, about half the weight of similar capacity water-cooled diesel engines.



Historical rice yield trends

We helped the BRRI adapt the PT3 power tiller for mounting the small diesel engines used with shallow well irrigation pump sets. Two prototypes of a detachable rotary tiller attachment fabricated at the Bangladesh Machine Tool Factory were field-tested by BRRI and IRRI engineers for performance and durability.

of irrigation systems. The Ganges-Kabodak irrigation system is a large-scale lift-*cum*-gravity scheme. The North Bangladesh tubewell irrigation system has 377 deep tubewells under its management.

Within the nine tertiary canal service areas of the Ganges-Kabodak irrigation system where intensive field research was conducted, average rice yields in aman season increased by about 1.0 t/ha in tailend areas and almost 0.5 t/ha in headend areas during the project period. The yield increases primarily were due to improved water management and the improved rice varieties introduced.

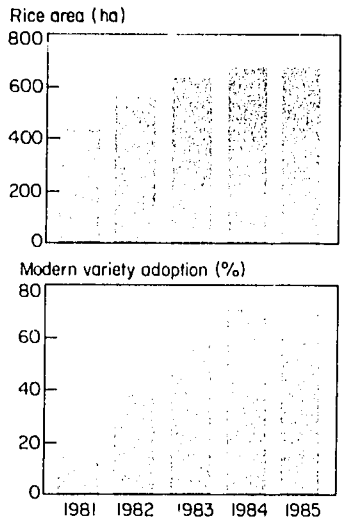
One study of the system recommended these strategies for improving and sustaining its irrigation effectiveness: 1) advance the pump operation schedule to 1 Feb-31 Oct, with rigorous adherence to the schedule, to establish a reliable irrigation program and to advance planting schedules in order to achieve higher yields; 2) develop a method to suspend pumping for 30-40 days in June and July to reduce system operational expenses; 3) delineate priority zones to be irrigated during the aus season, with compensatory attention given to areas outside the priority zones for timely aman rice cultivation; and 4) systematically

implement the 6-day rotation water delivery system that farmers find useful and acceptable.

In a 12-tubewell sample area of the North Bangladesh tubewell system, aman rice and rabi wheat production were increased by systematically improving the reliability of irrigation water supply, introducing suitable modern varieties, and providing support to farmer organizations. Modern variety use in the 1985 aman season was 52% in tubewell areas outside the sample and 72% within the sample area (Fig. 49).

In experiments in 1983 and 1984, growing green manure crops using rainwater during the normally fallow aus season, about 1.0 t/ha higher rice yields were obtained in the aman season with about 50% less N use.

In 1986, farmers grew green manure crops on more than 800 ha within the tubewell irrigation system command, where no green manure crop had been grown before.

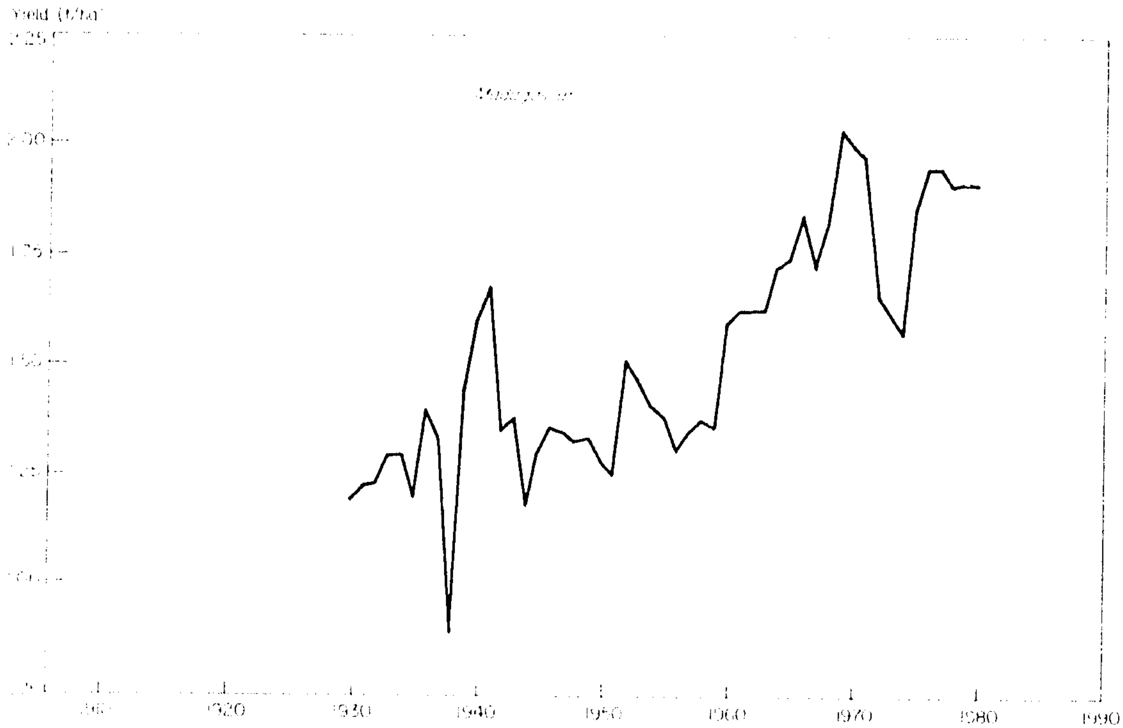


49. Aman rice area and modern variety adoption in the North Bangladesh tubewell irrigation system service area, 1981-86.

Madagascar

During the 2-1/2 years of the Madagascar-IRRI collaboration, a Malagasy rice research team composed of scientists, agricultural technicians, and administrators from several departments of the National Center for Applied Research on Rural Development (FOFIFA) was formed.

In addition to IRRI's resident team leader/agronomist and plant breeder, a number of IRRI consultants worked with Malagasy scientists this year on research station



Historical rice yield trends

development and management, soil fertility and adverse soil problems, agricultural machinery, agro-economic research, and rice environment mapping.

Training is an important component of the project, with 11 Malagasy scientists so far graduated from IRRI training courses and several more scheduled to participate in the near future. In addition, an in-country training course was conducted for FOFIFA research assistants and field technicians.

The rice research program moves forward steadily: 870 varieties have passed quarantine and 456 cultivars have been tested on research stations or in farmers' fields at 10 locations representing major rice environments. On the tropical west coast, under moderately low inputs, new materials are yielding 50% more than the local check. On the high plateau, on-farm cropping systems research is underway in three different environments. INSFFER trials are being conducted both on-station and on-farm.

Near Lac Alaotra and Marovoay — major rice producing areas of Madagascar — large tractors have serious problems in the soft soil of flooded ricefields. Lack of spare parts and high maintenance costs also are problems. But labor shortages during planting and harvesting that are beginning to occur delay crop establishment and cause excessive losses when harvesting and threshing are not timely. Introducing appropriate small farm machines will help increase cropping intensity and production.

An IRRI engineer helped the Division of Machinisme Agricole of the FOFIFA Department of Technology set research objectives, priorities, and strategies for establishing an agricultural mechanization program. Farmers' needs for equipment and machinery were assessed and IRRI machines for land preparation, harvesting, and threshing tested.

The first phase of development of the Rice Research Station at Mahitsy has been completed. The station eventually will include offices, laboratories, a medium-term germplasm storage facility, documentation center, and dining facilities.

Bhutan

We have been collaborating with the Royal Government of Bhutan since 1983 in developing and introducing appropriate technologies which can increase productivity in the country's rice-growing areas. The major thrust has been institution building, primarily through human resource development. Since 1983, 14 Bhutanese have been trained at IRRI. The superintendent of the main crop research station has begun a Master of Science degree program under the collaborative arrangement between IRRI and UPLB.

We are also working closely with the Bhutan Department of Agriculture to improve rice-based farming systems. Initially, the collaboration has focused on the medium (1000-1500 m) and lower altitude (<300 m) rice-growing areas that represent about 80% of Bhutan's 31,000 ha of riceland (Fig. 50).

In on-farm demonstrations and variety trials at Wangdiphodrang and Punakha this year, IR36 and IR64 showed excellent adaptation at 1300-1500 m. In 13 farmers' field demonstrations with farmyard manure as the only fertilizer, IR36 yielded 5.0 t/ha; local varieties yielded

50. The medium and lower altitude areas of Bhutan represent about 80% of the rice-growing area.

4.2 t/ha. With 30 kg N/ha as topdressing, IR36 yielded 5.7 t/ha. Local variety yields were unusually high because of favorable climatic conditions, but lodging was widespread.

In a set of replicated variety trials, the local variety yielded 4.5 t/ha, IR36 yielded 5.0 t/ha, and IR64 yielded 5.2 t/ha.

One constraint to adoption of modern high yielding varieties in Bhutan may be their straw production (Fig. 51). Rice straw is an important source of livestock feed and bedding. The low input demonstration trials indicate that IR36 produced an estimated 40% less straw than the local variety. There are indications that Bhutanese farmers prefer IR64 because it is taller than IR36.

In the lower altitudes of southern Bhutan, rice yields are restricted by poor soil fertility and disease and pest problems. Several promising rice varieties have been identified and green manure crops have been introduced. At Bhur Experiment Station, Gaylegphug, incorporating sesbania increased IR36 yields from 1.3 t/ha to 1.9 t/ha.

Indochina

IRRI entered into a Memorandum of Understanding with the Government of Australia early in 1986 to address the problems of rice production in the Indochina region that includes Kampuchea, Laos, and Vietnam (Fig. 52).

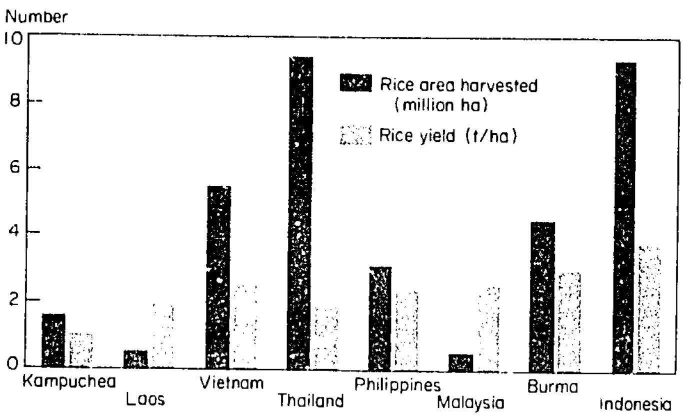
In January 1986, an IRRI team visiting Kampuchea identified several areas where IRRI might contribute significantly to the acceleration of rice production. The team's observations were the basis for a proposal submitted to the Australian Government in June 1986 that calls for a comprehensive program by IRRI (Fig. 53).

This region has considerable potential for greater rice production. The IRRI Indochina Program will address country-specific needs, with annual work plans developed jointly with each participating country.

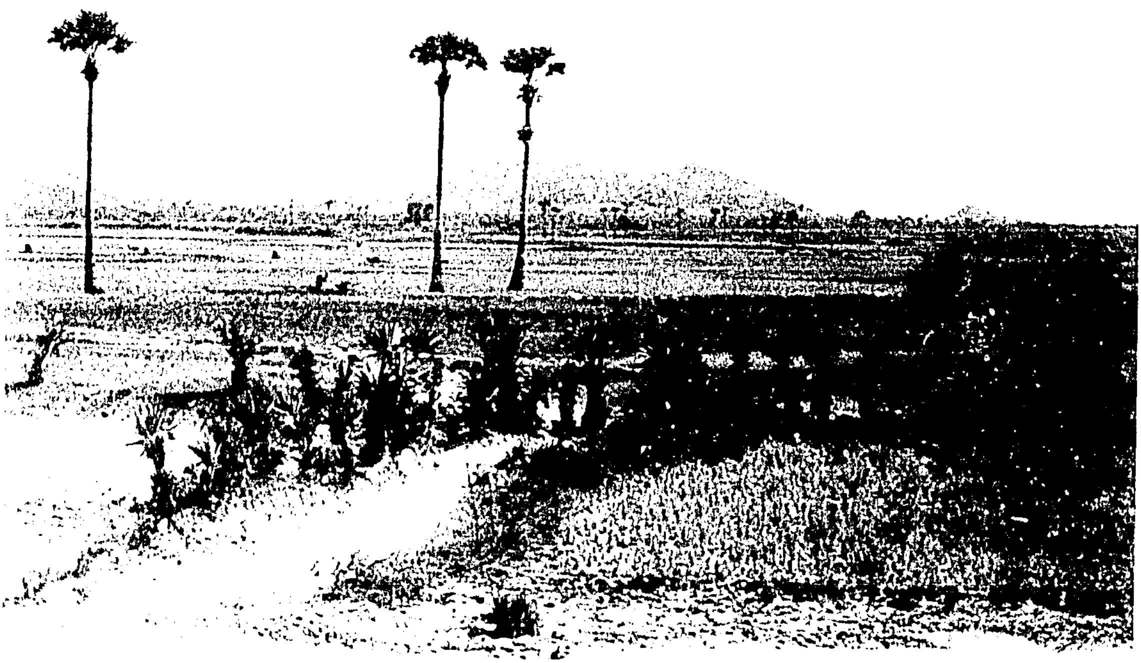
The goal is to assist Kampuchea, Laos, and Vietnam in developing and introducing appropriate technologies which can increase productivity in the region's rice-growing areas while increasing the income and nutrition of small farm households and communities. Over the next 10 years, the IRRI Indochina Program will work to meet these objectives:

- To develop manpower capability in rice research and development within Kampuchea, Laos, and Vietnam;
- To provide technical assistance in the design, implementation, and analysis of research to develop improved rice-based farming systems;

51. Bhutan farmers prefer taller varieties that have a high straw yield, an important source of livestock feed and bedding.



52. FAO 1983-85 data on rice area harvested and rice yields in selected Southeast Asian countries.



- To assist in the development of research and training infrastructure; and
- To help the countries attain and maintain self-sufficiency in rice.

During the exploratory and establishment phase, particular emphasis will be given Kampuchea because of its extremely low yields in comparison with other countries in Southeast Asia.

CONTINUING COLLABORATION

hese dynamic collaborations propel IRRI's research productivity. As we examine our progress in meeting research goals set through our interactions with rice researchers all over the world, and as we work to establish our goals and strategies for the future, we continually recognize — and utilize — our current relationships.

At the same time, we reach out for new relationships on basic and strategic research frontiers. And, we respond to the evolving needs and capacities in applied and adaptive research. Our strategy is to promote the expansion and increasing capability of a global, interactive scientific community in rice research.

◄

53. An IRRI team and Kampuchean scientists survey areas where IRRI might contribute to accelerating rice production.

FINANCES

Summary of financial support to IRRI core and to special and collaborative projects received in 1986.[a]

	US$			
	Core		Special & Collab. Proj.	Total
	Unrest.	Rest.		
Details of sources of support from grants				
United States Agency for International Development	6,050,000		2,231,825	8,281,825
Japanese Government		5,205,670	884,182	6,089,852
International Bank for Reconstruction and Development	1,500,000			1,500,000
Canadian International Development Agency	1,229,950		1,196,259	2,426,209
United Nations Development Programme		2,183,900	42,937	2,226,837
European Economic Community		**3,574,980**		3,574,980
Overseas Development Administration, United Kingdom	1,140,102			1,140,102
Federal Republic of Germany	460,793	150,000	235,440	846,233
International Development Research Centre		**110,190**	624,822	735,012
Australian Government	573,549		123,391	696,940
Government of Italy	173,853	**537,307**		711,160
Asian Development Bank			300,000	300,000
Government of Sweden	440,964			440,964
Government of the Netherlands			141,692	141,692
International Fund for Agricultural Development		**300,000**		300,000
Government of the Philippines	108,820		82,029	190,849
Ford Foundation	**300,000**	**70,000**	98,500	468,500
Government of Denmark	266,102			266,102
Office of Rural Development, Korea			98,000	98,000
Government of Mexico	**37,022**			37,022
Government of Norway	136,027			136,027
Government of China	100,000		20,000	120,000
Swiss Development Cooperation		**350,000**	45,000	395,000
Rockefeller Foundation		**704,740**	86,853	791,593
Government of Spain	**35,000**			35,000
Government of New Zealand	12,537			12,537
Government of France			74,074	74,074
Miscellaneous research grants			102,374	102,374
Funds reimbursed under collaborative research program				
Resource Management International, Indonesia			134,018	134,018
International Food Policy Research Institute			104,318	104,318
International Institute of Tropical Agriculture			61,729	61,729
International Centre of Insect Physiology and Ecology		**120,221**		120,221
International Fertilizer Development Center			30,769	30,769
International Board for Plant Genetics Resources			21,647	21,647
Food and Agriculture Organization of the United Nations			14,000	14,000
Total	12,564,719	13,307,008	6,753,859	32,625,586

[a]Receipts are accounted for on a cash basis. Amounts shown in boldface differ from 1986 pledges from grantors in that they may reflect 1985 or 1987 pledges received in 1986, or may not reflect the full amount of 1986 pledges which are anticipated to be received in 1987. The Government of France (through the research organizations ORSTOM and IRAT) provided IRRI the services of two resident scientists; the value of their services cannot be quantified.

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[1]Left during the year
[2]Joined during the year
[3]Joined and left during the year
[4]Cooperative research staff
[5]Transferred